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Visibility Benefits Assessment Guidebook
Final Report

Abt/West
Denver, CO

Prepared for

Environmental Protection Agency
Research Triangle Park, NC

Aug 81

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Research Triangle Park NC 27711

EPA-450/5-81-001
August 1981

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Final Report

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This guidebook presents concepts and techniques that can be used to estimate monetary benefits for changes in visibility aesthetics resulting from alternative levels of air pollution control. There are several defensible methodologies that can be used to place a monetary value on visibility aesthetics. This guidebook focuses upon this one aspect of air quality analysis, which can be combined with other aspects, such as health damages of air pollution and costs of emission controls to producers, to assist in policy decision making relating to air quality management. This guidebook introduces these benefit estimation techniques in recognition of the EPA's need to provide technical support to those who must evaluate impacts related to clean air regulations and in recognition that improved benefit measurement will lead to more accurate benefit-cost analysis. Finally, documentation of the assumptions, strengths, and limitations of each method provides inexperienced users with some technical basis for interpreting the results of the various approaches.

KEYWORDS: *Visibility, *Air pollution, *Guidelines, *Air
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Visibility Benefits Assessment Guidebook

Final Report

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PREFACE

This guidebook was prepared for the Office of Air Quality Planning and Standards as part of its Economic Benefit Program. The U.S. EPA recently promulgated visibility regulations persuant to the Clean Air Act. These regulation do not, as of yet, explicitly mandate the use of benefit cost analysis (BCA) in the implementation process. But, they are implicitly required, have frequently proved appealing and may currently be required by virtue of Executive Order 12291 for major new regulations. The guidebook enhances the likelihood of high quality BCA in visibility related environmental work by demonstrating how explicit measurement of aesthetic benefits can be accurately estimated and by providing a comprehensive and critical assessment of the current state-of-the-art.

This effort has greatly benefited from Myrick Freeman's book The Benefits of Environmental Improvement; however, we have attempted to assist a larger audience by giving a broader foundation in economics and research methodology. Also, by focusing upon visibility benefit analysis, we are able to give an in-depth treatment to technical non-economic aspects of the aesthetic impacts of air pollution, a balanced examination of alternative techniques used in air quality benefit analysis, and 10 detailed case studies.

We would like to thank Mr. Tom Walton, who served as the EPA Project Manager and provided many helpful comments. Drs. V. Kerry Smith and Ray Palmquist provided considerable assistance from project design to commenting upon the entire manuscript. Ron Henry of ERT, Inc. significantly contributed through his development and writing of Chapter 3. We would also like to thank Jan Laarman, Allen Basala, Alan Randall, Hugh Devine, Anne Bresnock, Edna Loehman and William Schulze for technical comments; Eric Walther and John Molenar for the sample slides; Winnie Hinton for editorial assistance; and Claudia Collins for production support.

The analysis and evaluations expressed in this guidebook are those of the authors and should not be interpreted as necessarily reflecting the official policies of the U.S. Government.

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CHAPTER 1

INTRODUCTION

1.1 Objectives of the Guidebook

This guidebook presents concepts and techniques that can be used to estimate monetary benefits for changes in visibility aesthetics resulting from alternative levels of air pollution control. Although monetary values are not commonly associated with visibility aesthetics, it is generally recognized that visibility conditions affect people's moods and influence many of their decisions. This indicates that people value visibility aesthetics and that visibility should be considered when examining the costs and benefits of changes in air quality.

There are several defensible methodologies that can be used to place a monetary value on visibility aesthetics. This guidebook focuses upon this one aspect of air quality analysis, which can be combined with other aspects, such as health damages of air pollution and costs of emission controls to producers, to assist in policy decision making relating to air quality management. Several best-practice techniques are discussed in terms of their application for evaluating existing or potential visibility impacts from single sources or for regional haze problems in recreational, rural and/or urban settings.

This guidebook introduces these benefit estimation techniques in recognition of the EPA's need to provide technical support to those who must evaluate impacts related to clean air regulations and in recognition that improved benefit measurement will lead to more accurate benefit-cost analysis. While visibility benefit analyses are not currently mandated by clean air regulations, this guidebook serves as a vehicle for making the best-practice techniques available to those who may undertake these efforts and serves as a quality control mechanism for those who may review these studies. Finally, documentation of the assumptions, strengths, and limitations of each method provides inexperienced users with some technical basis for interpreting the results of the various approaches.

1.2 The Need for Economic Benefit Analysis

The value of preserving scenic and natural settings has long been recognized in maintaining national parks, monuments and other recreational areas. Section 169A of the Clean Air Act, added in 1977, established a national goal of remedying existing and preventing future manmade visibility impairment in mandatory Class I Federal areas. Recently, 156 of these areas were identified in which visibility is an important value. Figure 1.1 shows these areas and the types of pollution affecting them. According to Federal land managers, roughly one-third of these areas have been found to have undesirable visibility conditions.

The value of air quality in urban areas has also been recognized. National Ambient Air Quality Standards that apply to urban areas are primarily aimed at the health aspects of air quality. Although government regulations do not now emphasize the aesthetic impacts of air pollution in urban areas, there is growing awareness that these impacts do occur and are closely related to residents' perceptions of air quality conditions.

Visibility benefit analysis is not specifically mandated in any clean air legislation, although the regulations do require consideration of costs and benefits for proposed changes in air quality. On December 2, 1980, the EPA published final regulations to implement selected visibility protection provisions in Section 169A and 165(d) of the Clean Air Act. These regulations provide for a phased approach to visibility protection. The first phase, now being implemented, deals with controlling impairment that can be traced to a single major source or a small group of sources. It specifically requires states with mandatory Class I Federal areas to incorporate certain measures into their State Implementation Plans (SIPs) that will assure reasonable progress toward the national goal of preventing future and remedying existing impairment of visibility in mandatory Class I Federal areas. The regulations further state that integral vistas, defined as important views from within mandatory Class I Federal areas of scenic landmarks or panoramas that extend beyond the boundaries of the areas, are to be considered in visibility impact determinations and that states and Federal land managers are to coordinate with each other through a formal process in impact determinations. The second phase regulations, which will deal with multiple source regional hazes and urban plumes as they affect mandatory Class I Federal areas, will be issued at a later date subject to research progress.

These regulations indicate that while there is a national goal of complete protection from visibility impairment in mandatory Class I Federal areas, there is some flexibility in determining whether any impairment should be allowed to exist or increase. This approach is reiterated in sections of the regulations that mandate control of existing sources, prevention of significant deterioration from new sources (PSD), new-source review requirements, protection of integral vistas, and state long-term strategies. For example:

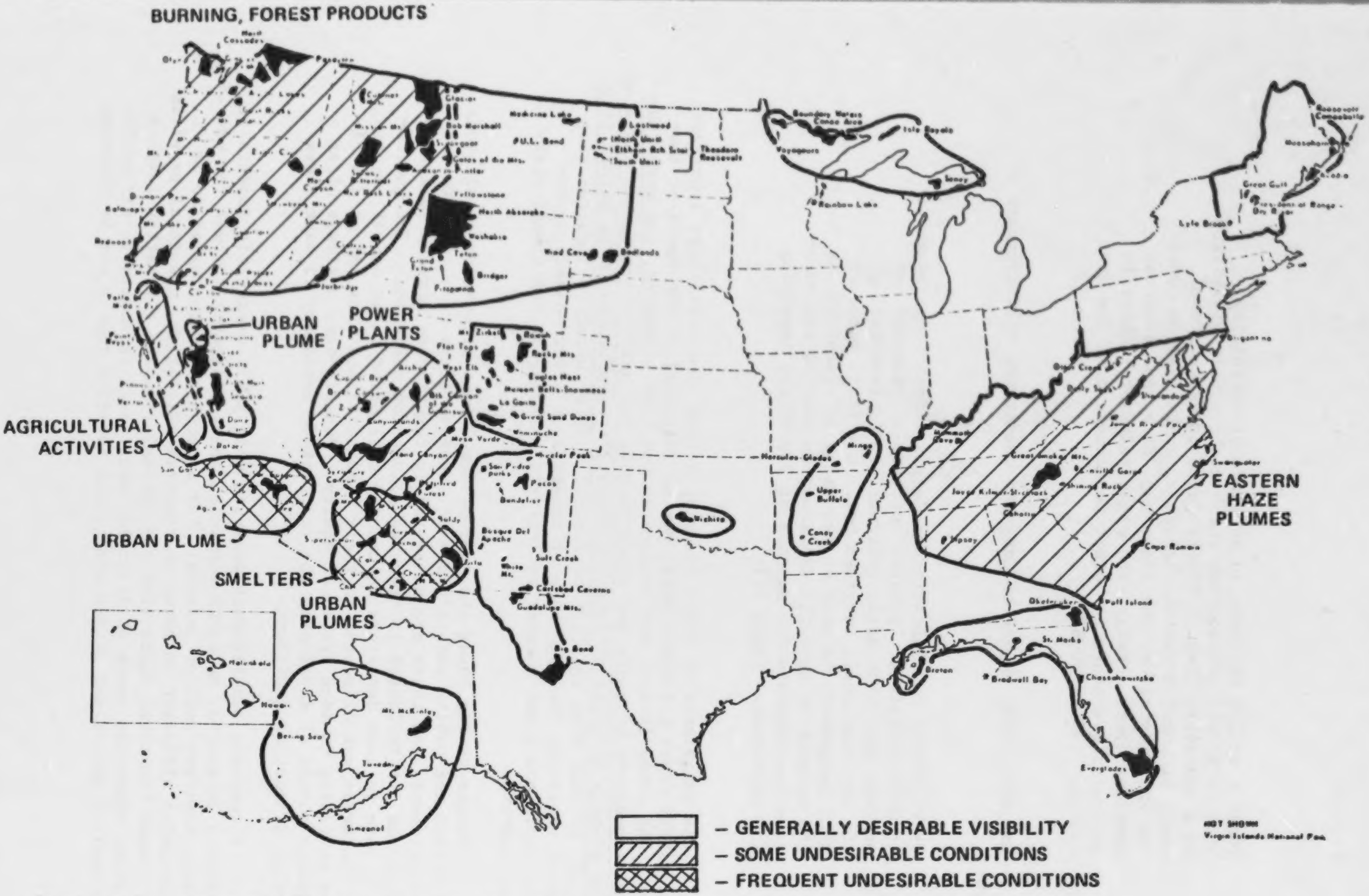
BURNING, FOREST PRODUCTS
URBAN PLUME
POWER PLANTS
AGRICULTURAL ACTIVITIES
URBAN PLUME
SMELTERS
URBAN PLUMES
EASTERN HAZE PLUMES
Yellowstone
Glacier
Bob Marshall
Medicine Lake
U.L. Bend
North Absaroka
Washakie
Teton
Grand Teton
Bridger
Wind Cave
Badlands
Theodore Roosevelt
Lostwood
Boundary Waters Canoe Area
Voyageurs
Isle Royale
Seney
Rainbow Lake
Rocky Mtn
Eagles Nest
Maroon Bells-Snowmass
La Garita
Great Sand Dunes
Weminuche
Mesa Verde
Grand Canyon
Flat Tops
Wheeler Peak
San Pedro Parks
Pecos
Bandelier
Bosque Del Apache
Salt Creek
White Mtn.
Carlsbad Caverns
Guadalupe Mtn.
Big Bend
Wichita
Hercules Glades
Mingo
Upper Buffalo
Caney Creek
Mammoth Cave
Great Smoky Mtn.
Shenandoah
James River Face
Shining Rock
Joyce Kilmer-Slickrock
Cohutta
Sipsey
Swanquarter
Cape Romain
Wolf Island
Okefenokee
St. Marks
Bradwell Bay
Breton
Chassahowitzka
Everglades
Brigantine
Lye Brook
Great Gulf
Presidential Range-Dry River
Moosehorn
Acadia
Roosevelt Campobello
Mt. McKinley
Bering Sea
Tuxedni
Simeonof
Haleakala
Hawaii
Redwood
Kalmiopsis
Point Reyes
Pinnacles
Ventana
San Gabriel
Agua Tibia
Superstition
Chiricahua
Gila
Joshua Tree
Dome
North Cascades
Pasayten
Olympic
Mission Mts.
Cabinet Mts.
Selway Bitterroot
Gates of the Mts.
Anaconda Pintler
Hells Canyon
Red Rock Lakes
Sawtooth
Craters of the Moon
Jarbidge
Capitol Reef
Arches
Canyonlands
Black Canyon of the Gunnison
Petrified Forest
Sycamore Canyon
Saguaro
Mt. Zirkel
NOT SHOWN
Virgin Islands National Park
▭ – GENERALLY DESIRABLE VISIBILITY
▨ – SOME UNDESIRABLE CONDITIONS
▩ – FREQUENT UNDESIRABLE CONDITIONS

Figure 1.1: Types of Pollution Impacts for Protected Class I Areas.

Source: Protecting Visibility, An EPA Report to Congress, 1979; page 5.

> Today's action requires an analysis of visibility impacts by all new sources which might impair visibility in a mandatory Class I Federal area irrespective of their proposed location. However, unlike review under the PSD provisions, the state may, for these sources, consider costs, energy, and other relevant factors in determining whether to permit construction of the new source. (45 FR 80088)

The EPA (1979) report to Congress summarizes this approach as follows:

> By requiring consideration of "significant" impairment in BART decisions, "adverse" effects of proposed new sources and "reasonable progress" in implementating the national goal, Congress has, in effect, mandated that judgements be made on the value of visibility in the context of specific decisions on control and location requirements for sources of visibility impairing air pollution. (Page 1.)

The importance of these clauses is that some visibility impairment in mandatory Class I Federal areas may be tolerated if the costs of compliance and other factors are considered too high. However, the magnitude of these measures of costs and other factors are only relevant when compared to the primary benefits of improved visibility aesthetics to be gained from control, or lost from the lack of control. This therefore requires some judgment regarding the magnitude of benefits in order to make appropriate decisions about whether to tolerate existing or additional visibility impacts.

Judgments regarding the appropriate levels of environmental goods fall within the public sector's domain, because these resources are not privately owned and there are no privately functioning markets to assure that values are reflected in resource allocation decisions. The government's role in such decisions is usually considered to be one of assuring that resources are allocated to their highest valued uses and/or distributed according to some system of equity. Benefit-cost analyses offer a pragmatic method of developing the information necessary to make these resource allocation decisions.

A complete benefit-cost analysis weighs all measurable impacts in a resource balancing, multi-objective planning framework through the use of a common monetary unit of measure. For a regulation or program to be economically efficient in terms of resource allocation, the total benefits must exceed the total costs with the optimal resource allocation level at the point where the costs of diverting additional resources to air pollution control are offset by the additional benefits that would be obtained.

The distribution among different population groups and different geographical regions of the benefits and costs of the program or regulation can also be considered in benefit-cost analysis. Among the costs that must be considered for this type of analysis are those of compliance, regulation and other environmental and energy impacts. The benefits include improved visual aesthetics and reduced damages to health and property.

Air quality analysis and legislation have often focused upon obviously measurable variables, such as chemical and physical characteristics and control costs, for decision-making purposes. These decisions implicitly set values on other seemingly non-quantifiable effects, such as aesthetic benefits, even though they may never have been explicitly considered.[1] When only the costs of air quality control are estimated and never the benefits, the decisions on the level and location of emission controls nonetheless reveal implicit benefit measures made by the decision makers (under the assumption that each decision was made rationally). However, there is no assurance that such implicit valuations are accurate reflections of society's actual benefits or consistent from one decision to the next. For example, in mandatory Class I Federal areas the national goal is to have no visibility impairment, implying that the benefits, which are primarily aesthetic, of eventually eliminating all impairment are expected to outweigh costs of control; in other situations some impairment is allowed, implying that the benefits of complete control do not outweigh the costs. Because few, if any, explicit benefit measures were used in these determinations, there is no assurance that the implied size of benefits was either correct or consistent, and therefore that the decisions were socially desirable.

The value of the research techniques discussed in this guidebook is that they allow explicit measurement of the aesthetic benefits to be achieved from air pollution control so that more accurate, economically efficient, and equitable resource allocation decisions can be made within the benefit-cost framework of analysis.

1.3 Overview of Visibility Benefit Analysis

A visibility benefit analysis is a complex research project that requires inputs from many disciplines. Figure 1.2 illustrates the steps that must be considered in a thorough economic analysis of visual aesthetics.

Steps 1 and 2. A benefit analysis must fully define the visibility problem under consideration. This includes describing the sources and characteristics of the alternative pollution levels, and dispersion modeling to determine when, where, and at what magnitude the impacts will occur. This is required if the benefit measures for visibility improvements are to be precisely related to the emission rates and costs of controls necessary to achieve the improvements.

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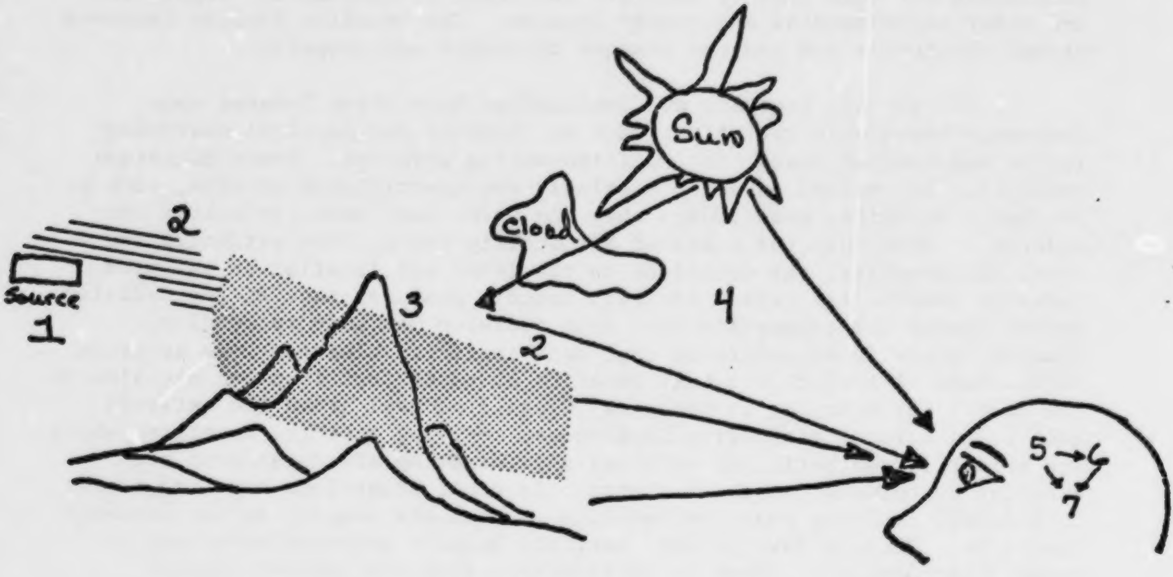
[1] For a discussion of the problem of non-quantifiables in benefit-cost analyses see Freeman 1970; and Sassone and Schaffer 1978.



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1. Source of pollutant, type, intensity, and frequency.
2. Spatial dispersion of pollutant and type of impact (plume, haze).
3. Scenic content of affected view.
4. Atmospheric conditions and transmission of visual images affected by lighting, cloud cover, etc.
5. Human perception of impacts.
6. Psychological effect of perceived impacts.
7. Economic valuations of impacts in terms of willingness to alter time or dollar expenditures.

Figure 1.2 Inputs to the Economic Visibility Benefit Assessment Process

Steps 3 and 4. It must be determined how the pollutants affect visibility as perceived by observers. This will depend upon the types of pollutants -- many cannot be perceived by the human observer -- and upon atmospheric conditions. For example, the light scattering effects of small particles cause more whitening of the horizon when the sun is located in front of the observer rather than directly overhead.

Steps 5 and 6. It must be established what aspects of the perceived visibility degradation will impair the observer's enjoyment or use of the view or location under study. The loss of the scenic content of an obstructed view may be important, as may be the loss of visual range or discoloration that may occur with increased pollution levels.

Step 7. How much effort the observer is willing to expend to avoid, reduce, or eliminate these impacts depends on the importance to him of the various visibility impacts of the pollutants, including the psychological effect. Economic benefit analysis techniques are the procedures used to quantify what this effort is worth in dollar terms, thus measuring part of the benefits of pollution control.

1.4 Guidebook Organization

The topics of each chapter of the guidebook are as follows:

Chapter 2. The conceptual economic framework and definitions of monetary benefit measures for visibility improvements derived from consumer utility theory and demand analysis.

Chapter 3. An overview of required inputs from other disciplines to aid the economic analyst in communicating with physical scientists, psychologists and sociologists in performing a complete benefit analysis.

Chapter 4 The applications, theoretical foundations and strengths and weaknesses of several economic techniques currently used to measure benefits of visibility and overall air quality changes.

Chapter 5. A summary of the start to finish research tasks for a complete visibility benefit analysis with suggested step-by-step decision and application guidelines.

Chapter 6. Five case studies of actual applications for both of the two predominant techniques--bidding methods and the hedonic property value approach--and a comparison of their procedures and results.

A glossary, annotated bibliography, and an appendix with sample picture sets and questionnaires for the bidding method are also included.

The nontechnical reader who desires an introduction to the estimation methods and their application should focus upon Sections 2.1, 2.2, 4.1 to 4.3, 5.1 and the relevant case studies in Chapter 6. The hedonic approach case studies and the South Coast Air Basin bidding method case studies are the most relevant for urban area pollution problems, while the bidding method case studies are more relevant to air quality issues in mandatory Class I Federal and other recreational and rural areas. Technical material is presented in Section 2.4 and the last portion of 4.3.2, and non-economics material is presented in Sections 3.1-3.7 Actual application of the benefit estimation methods will require mastery of much of the material in these sections.

Though visibility aesthetics are the focus of this guidebook, some of the techniques discussed are equally applicable for estimating other benefits from the control of air pollution, such as reduction of health and materials damage. The guidebook also emphasizes visibility in recreational areas, particularly in the West, because the focus of the regulations is mandatory Class I Federal areas, the majority of which are located in the West, and because the most recent empirical work has been in the western U.S.

Several other EPA reference documents will be especially useful for visibility benefit analysis:

1. Protecting Visibility: An EPA Report to Congress (EPA-450/5-79-008).
2. The Development of Mathematical Models for the Prediction of Anthropogenic Visibility Impairment (EPA-450/3-78-110 a, b, c).
3. Guidelines for Determining Best Available Retrofit Technology for Coal-Fired Power Plants and Other Existing Stationary Facilities (EPA-450/3-80-009b).
4. Assessment of Economic Impacts of Visibility Regulations (EPA-450/2-80-084).
5. User's Manual for the Plume Visibility Model (PLUVUE) (EPA 450/5-80-032).
6. Workbook for Estimating Visibility Impairment (EPA 450/4-80-031).
7. Interim Guidance for Visibility Monitoring (EPA 450/2-80-082).
8. Visibility Protection for Federal Class I Areas (45 FR 80084-80095).

All the above documents are available from National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

CHAPTER 2

ECONOMIC BENEFIT MEASURES

Performing a benefit-cost analysis of changes in visibility aesthetics, or in other air quality conditions, first requires a careful definition of what the benefits are and how monetary measures of these benefits are defined. This is particularly important for visibility aesthetics, because the concepts of visibility as an economic good and monetary benefits of visibility improvements may not be immediately apparent. This chapter draws upon economic theory to describe the concept of an individual's welfare and to develop correct monetary measures of benefits for visibility aesthetics. The aggregation of benefits across individuals and through time to obtain total benefit measures for use in benefit-cost analysis is presented in a subsequent section. The chapter concludes with technical models of consumer behavior that can be used to derive benefit measures. The application of these theories of value requires precise definitions and measures of visibility. This topic is deferred to Chapter 3 where physical measures of visibility, what aspects of visibility are demanded and how the objects viewed affect visibility are discussed.

Before proceeding into a substantial volume of material, matters will be simplified by the use of several conventions. First, since damages from environmental degradation may be viewed as negative benefits, these terms--benefits and damages--may be used interchangeably. The term "costs," meaning the monetary charges incurred to implement a change, is not interchangeable with damages or benefits. In benefit-cost analysis, it is the difference between benefits and costs which is examined to determine whether a project represents an economically efficient allocation of resources to their highest valued uses. Second, the economic analyses presented can be used for most any economic good or environmental quality variable including air quality characteristics. Hence, the terms "air quality," "visibility aesthetics," and "environmental quality," while having different connotations in application, are used interchangeably in this chapter.

2.1 Concepts and Measures of Benefits

2.1.1. Concepts of Benefits

Economists generally perceive all things as having value. A measure of value is the well-being, or what economists call utility, derived from the consumption of a good or service. Similarly, any change in the level of consumption also has a value associated with it as long as someone's utility is affected. This change in utility may be viewed as either a benefit or damage, depending upon whether the individual's well-being is enhanced or diminished. Goods and services that are bought and sold in the marketplace, such as automobiles, haircuts, and blue jeans, are easily recognized as having economic value because individuals part with their scarce income to purchase them at market prices and forego purchasing other goods and services that could have also increased their well-being. The market price they are willing to pay for these goods therefore represents a minimum monetary measure of value to the consumer from their consumption in terms of alternative goods and services foregone.

Most environmental goods, such as air quality, are public goods. Once public goods are provided to one individual, it is difficult to exclude others from their consumption. Also, once provided to one individual the additional cost of providing them to others is zero. For example, if the air quality in a region is improved for the benefit of one group of individuals, it would be hard to exclude others in the region from also sharing the benefits or to charge a price for the consumption of the good. Consequently, public goods such as air quality are not exchanged on a market and do not have explicit prices. This does not mean they do not have value. People change their recreation patterns, move their residences, or simply alter their moods due to the existing level of air pollution. These non-market goods affect our well-being, and consequently, they have implicit values. By analyzing how individuals react to air quality changes, the value they place on air quality may be revealed.

There are three types of air quality values commonly addressed: activity value, option value, and existence value. Activity value (also called user value) is the value in use, i.e., enjoyment of the visibility at a site when one is actually there. Option value is the value assigned to the option of preserving some air quality level in anticipation of potential future activity at the site. It is the value of preserving the option that the activity value will be available at a later time based upon some non-zero yet uncertain probability that one will enjoy the visibility of the site at a later date.[1] It is important to note that option value is a value above and beyond the activity value. Existence value is the value assigned to the existence of a certain level of visibility aesthetics at a site even though one does not ever intend to participate in activity at the site. This may be tied to the philanthropic goal of preservation so that future generations may have the option of enjoying consumption of the good. Some authors also call this "preservation value," or "bequest value."

Activity, option and existence values are not unique to visibility aesthetics; they can also be applied to wildlife, Rolls Royces or any economic good. An aspect which is not often considered for air quality is its secondary consumption, such as in calendar pictures and post cards. These are on a fine line between activity and existence values but are usually assumed to have a significantly smaller value than on-site activity, option and existence values, and subsequently are less frequently analyzed.

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[1] A discussion of option values is found in Cicchetti and Freeman (1971), and Schamlensee (1972). A related concept, "quasi-option value", has also emerged. It is the expected value of remaining flexible as opposed to being committed to a longer course of action, or of making step-by-step decisions rather than once and for all decisions. See Arrow and Fisher (1974) and Miller and Lad (1981).

2.1.2 Monetary Measures of Benefits

The benefits to an individual from a change in visibility aesthetics equal the change in his well-being, a value which is difficult to quantify. Economic benefit measures address the problem by attempting to put a monetary quantification on changes in well-being. The monetary measure of benefits for a change in air quality is said to equal the change in income that would yield the same change in an individual's well-being. This monetary quantification has advantages and disadvantages. The advantages include the use of a common unit of measurement which, in many cases, can be readily observed in real market situations and is easily understood, added, and compared to costs of proposed changes by policy makers. A principal disadvantage of monetary quantification for visibility is that units of quantification are not as easily defined or measured, as is the case with market goods. The ability to use market data is a determinant in the choice of methodology used to obtain benefit measures for visibility valuation (see Chapter 4.) A second disadvantage relates to the issues of equity and intensity of preference across individuals. In order to measure the total welfare change society undergoes as the result of an action, it is necessary to combine or compare the welfare changes for all affected individuals. Even if the benefits or damages of a proposed change can be measured in dollars for each affected individual, combining these values requires some explicit consideration of the relative importance of impacts to the individuals. This issue is discussed in Section 2.3.

In some instances the researcher will simply be unable to obtain monetary measures of benefits. There are other methods which may be used to arrive at decisions about the relative value of visibility that do not use dollars, including preferability orderings, semantic differentials, weighting of multiple objectives, and the like (see Sinden 1979). These methods do not allow measurements of the change in utility, but they do, for instance, indicate the concentration of haze in the Blue Ridge Mountains at which the recreation experience ceases to be pleasant (or utility ceases to be positive), or the relative importance of air quality levels versus other concerns of society. Thus, these methods indirectly aid decision making by accounting for reactions to proposed changes. This is not picking up "value" in its true sense, but is indeed capturing "valuation." In many cases these techniques are worthwhile undertakings before a monetary benefit analysis is performed. By determining the characteristics of an experience that are most important to affected individuals, they help focus the subsequent monetary benefit analysis upon these important characteristics. A recent example of one such non-monetary valuation for potential visual and visibility impacts of nearby strip mining upon Bryce Canyon National Park can be found in U.S. NPS (1980). While these approaches are useful, it is the focus of this guidebook to examine monetary measures of benefits for incorporation into benefit-cost frameworks.

Three monetary measures of value used by economists in benefit analysis are willingness to pay (WTP), expenditures, and consumer surplus. "WTP" is the maximum amount an individual would be willing to pay for a good or service, representing its maximum monetary value to the individual. In many cases price is an accurate reflection of the maximum WTP for additional units of a good or service. "Expenditures" represents the actual amount a consumer spends for a good or service (price times quantity), which in a situation of free choice would never be greater than his maximum WTP for all of the units consumed. However, an individual may be fortunate enough to spend less than his maximum WTP. This surplus value, or the difference between the maximum WTP and expenditures, is commonly referred to as "consumer surplus."

Consumer surplus is an especially important concept because changes in consumer surplus equal the monetary measure of benefits from changes in air quality. In many cases visibility aesthetics do not have a market price and there are no expenditures, so that consumer surplus equals the maximum WTP for all units consumed and is all that is affected by changes in visibility conditions.

The Demand Curve Approach to Monetary Measures of Benefits

Demand curves can be used to measure maximum WTP, expenditures, and what is called ordinary consumer surplus.[2] A demand curve is the relationship between the amount of a good or service demanded and the maximum WTP for it in terms of price. As shown in Figure 2.1, where P1, P2, Q1 and Q2 are specific price and quantity levels of some good, a demand curve typically is downward sloping. While this need not be the case, empirical research nearly always supports this law of demand. This is, in part, due to the law of diminishing marginal utility, which is that each additional unit consumed yields a smaller increase in total utility, and therefore the individual's WTP for additional units also decreases. The quantity demanded by a consumer depends on the price of the good, the prices of other goods, the consumer's income, and his tastes and preferences. Because the demand curve is the relationship between price and quantity demanded, a change in the price of the good results in a movement along the demand curve, whereas a change in the other things that determine demand will shift the demand curve. For example, an increase in income may increase the quantity that a consumer is willing and able to buy at each price.

A demand function can be mathematically illustrated as follows:

$$Q_d = f\ (P_x, P_o, M, T)$$

Where:

Q_d = quantity of good x demanded

P_x = prices of good x

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[2] Those unfamiliar with the fundamentals presented in this section are referred to any standard intermediate microeconomic theory text such as Hirshleifer (1976).

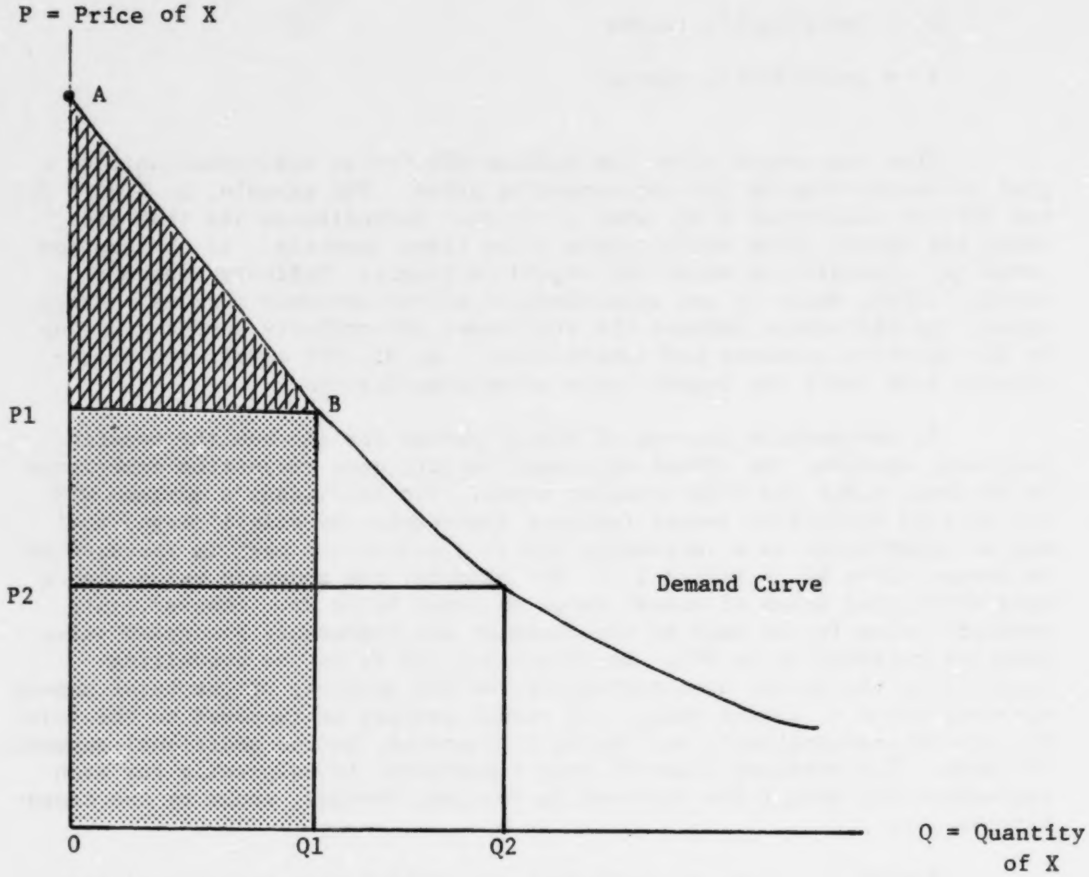


Figure 2.1

Demand Curve For A Typical Good X

P_o = prices of other goods and services

M = individual's income

T = individual's tastes

From the demand curve the maximum WTP for an additional unit of a good is represented by the corresponding price. For example, in Figure 2.1 the WTP for additional X at level Q1 is P1. Expenditures are that area under the demand curve which equals price times quantity. At consumption level Q1, expenditures equal the shaded rectangle. Ordinary consumer surplus (OCS), which is one approximation of the consumer surplus concept, equals the difference between the area under the ordinary demand curve up to the quantity consumed and expenditures. At Q1, OCS equals the cross-hatched area under the demand curve above expenditures.

To demonstrate the use of demand curves for air quality benefit analysis, consider the effect of visual quality upon recreation experience in national parks and other similar areas. The individual's maximum WTP for various visibility levels (perhaps represented by visual range) that may be experienced on a recreation day in a particular park is represented by demand curve DD in Figure 2.2. For example, the monetary value placed upon additional miles of visual range at level V1 is W1. However, this monetary value is not paid by the consumer and represents a surplus value commonly referred to as OCS. In Figure 2.2, if V1 is the prevailing visibility, the dotted area represents the OCS measure, or the total unpaid monetary value of visual range. If visual quality is improved to the level V2, the recreationalist's well-being is improved, but no additional payments are made. The monetary value of this improvement in well-being for each recreation day equals the increase in consumer surplus, shown by the cross-hatched area.

Figure 2.3 gives an equivalent and perhaps more operational presentation of willingness to pay for visibility. Here the demand for recreation days is represented as a function of the price per day, including entrance fees, food, variable expenses, value of time, and the like. In this approach the demand for recreation days shifts as a function of visual quality at the recreation site. If P represents the daily entrance price and other daily costs, and visual quality is 50 kilometers, then R1 recreation days are demanded. Total expenditures are represented by the area OPAR1 and consumer surplus by the area PCA. If visibility increases to 100 kilometers, demand to participate in recreation at all prices can be expected to increase, perhaps to D2. At price P, R2 days are now demanded and expenditures increase to the area OPBR2. Total consumer surplus increases to the area PDB. It can be seen that not only is it likely that the consumer surplus attached to each recreation day increases but the number of days spent in the activity also increases.

Because the increased expenditures occur at the expense of decreased expenditures on other goods and services, they do not represent an

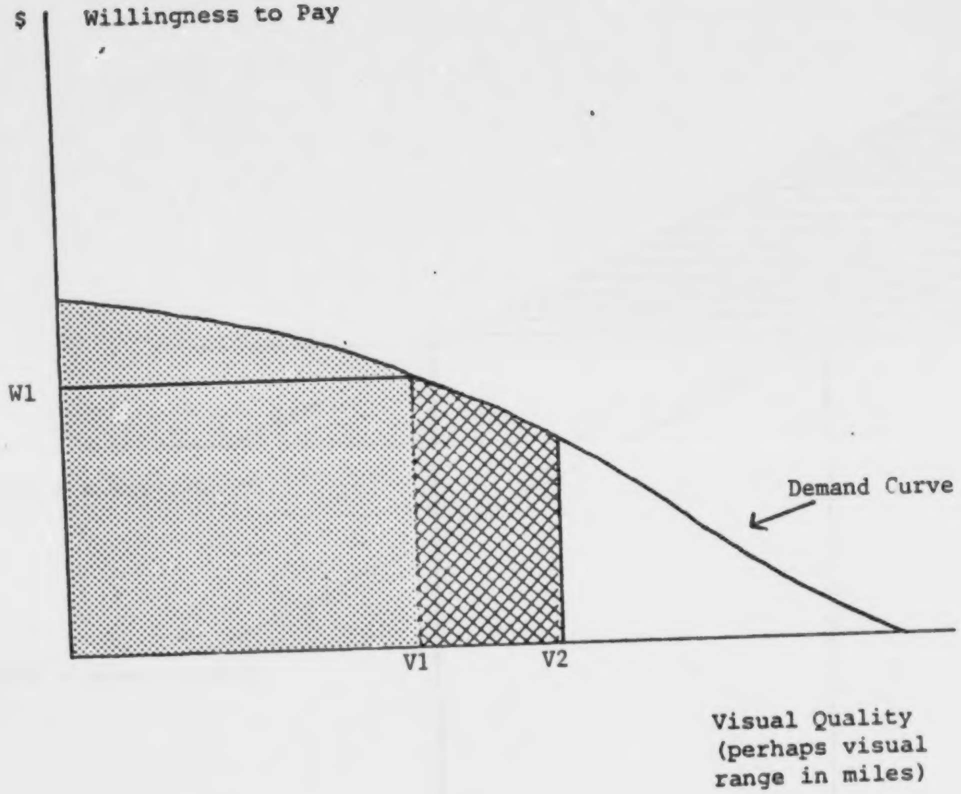


Figure 2.2

Willingness To Pay For Visibility In The Recreation Experience

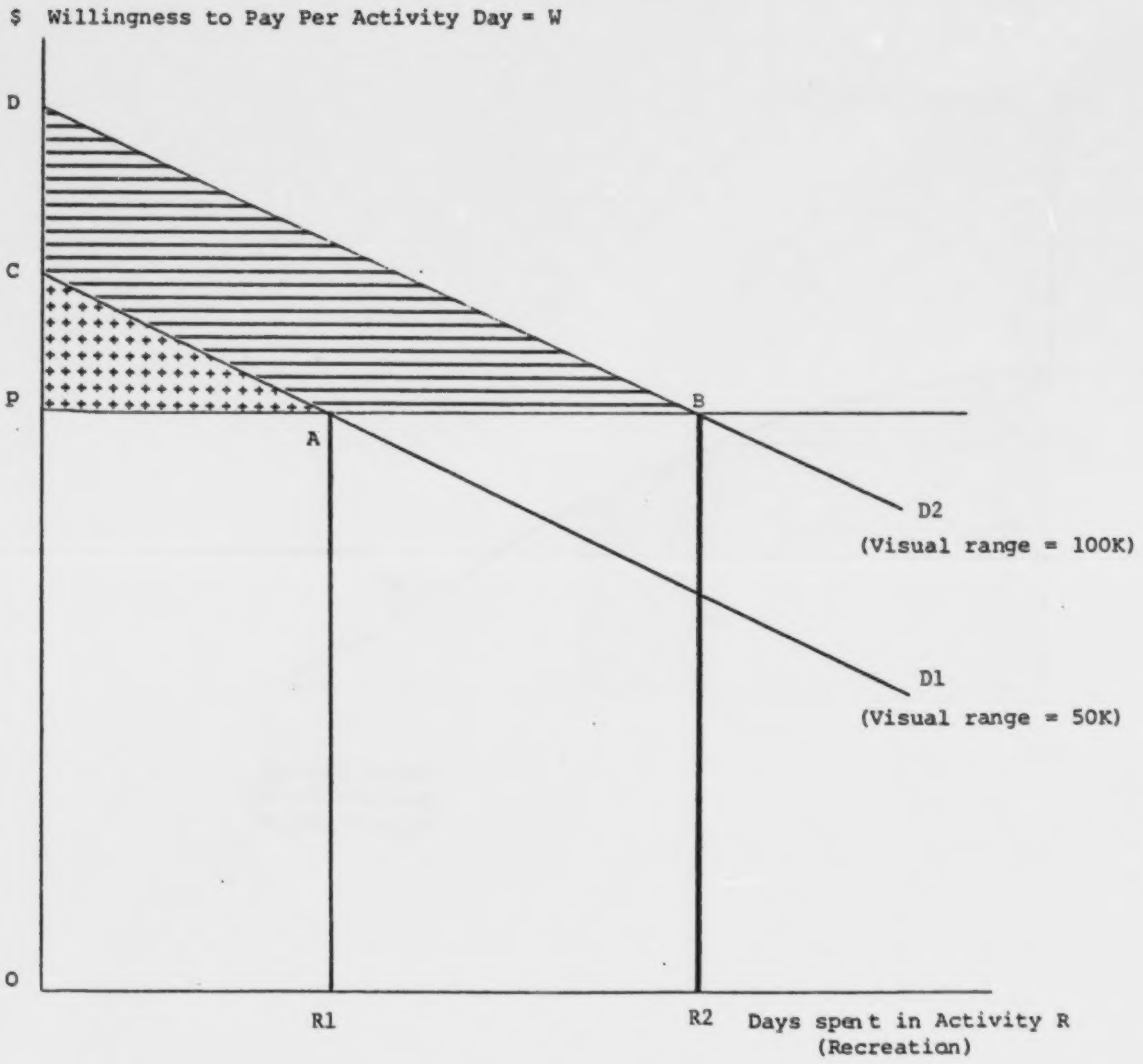


Figure 2.3

Demand for Activity Days as A Function Of Price And Visual Range increase in utility, but rather a shift in consumption from one good to another. The change in OCS, represented by the area CDBA, is a monetary measure of the change in an individual's utility for the change in visibility because it represents the WTP for the change in excess of expenditures. This change in OCS accurately reflects the monetary meacure of the change in an individual's utility under special conditions, such as small income effects and weak complementarity, described further after more theoretical foundations are established.

Factors affecting the location, steepness and shifts in the demand curve and, consequently, in the consumer surplus measure, include availability and cost of alternatives, special characteristics of the site, user population location, income, and other socioeconomic variables. The travel cost approach described in Chapter 4 is an attempt to derive benefits for visibility changes by estimating this type of demand curve for recreation and by estimating changes in this demand as visibility changes.

In many markets, such as housing, the WTP for housing may similarly be influenced by local air quality conditions. As described in Chapter 4, by investigating market prices, house and buyer characteristics, and air quality characteristics, price functions for property values as a function of visibility can be estimated, from which implicit demand curves for visibility, such as that shown in Figure 2.2, can be estimated and monetary benefit measures obtained.

Unfortunately, demand curves for market goods as a function of air quality characteristics are often very difficult to estimate because appropriate data are often unavailable. Researchers may attempt to estimate changes in consumer surplus by direct questioning of individuals about their WTP or their behavior as air quality changes (described in Chapter 4). The correct application of this and the above mentioned techniques to obtain benefit measures requires very carefully defined measures of consumer surplus other than the OCS measure thus far described.

2.2 Refined Consumer Surplus Monetary Measures of Benefits

Consumer surplus plays a critical role in valuing a change in air quality. Unfortunately, the OCS measure illustrated in the previous section is not a technically correct measure of the consumer surplus concept. Because of this, several refined measures have been developed to accurately define and estimate this monetary measure of benefits. Understanding the deficiencies in the OCS measure and using and understanding the refined measures first requires knowledge of the basic economic framework used to analyze consumer behavior.

2.2.1 The Utility Map Framework Used to Define Consumer Surplus Measures

All theories of consumer behavior begin with the assumption that consumers make rational choices concerning the allocation of their resources with the ultimate goal of maximizing their own satisfaction or total utility, which is the sum of the utility from all goods consumed. Because the choice facing each consumer is not usually whether to buy all or none of a particular commodity, marginal utility, or the additional satisfaction derived the last additional units of a good consumed, is as important to decision making as is total utility.

The standard paradigm used to illustrate the utility maximization problem, which is the allocation of income to alternative uses so as to maximize total utility, is the indifference map illustrated for two goods, X1 and X2, in Figure 2.4. (This type of analysis can be applied to any number of goods or services.) An indifference map is a set of indifference curves, such as I1, I2, and I3, each representing various combinations of the two goods which yield the same level of utility to the consumer. Curves further away from the origin represent higher levels of utility. The shape of the curves are based upon standard and generally well substantiated assumptions about the theory of choice and consumption. One of the most important assumptions is that of diminishing marginal utility--that the additional utility derived from consuming an additional unit of a good decreases as the total consumption of the good increases. The shape of the indifference curves reflects diminishing marginal utility, because as consumption of one good increases, the increase in utility will be offset by smaller and smaller decreases in consumption of the other good.

If the prices of goods X1 and X2 are given as PX1 and PX2 and the consumer's income is M, a budget line AC may be drawn. All points on or to the left of AC represent bundles of goods X1 and X2 which may be purchased with income M. The highest utility level that may be reached with this income constraint, representing the consumer utility maximum, is on I2 at point B. By varying the price of one of the goods and locating each new consumer maximum point, it is possible to trace out the quantities of the good that would be purchased at each price, and with these price and quantity combinations to plot the previously illustrated classic demand curve for that good.

Returning to consumer surplus, Alfred Marshall defined it in his Principles of Economics (1930) as the excess of what the consumer would be willing to pay rather than go without the good, over that which he actually does pay. This clearly is the difference between the individual's maximum willingness to pay for all units and his actual expenditures. Marshall's "consumer's surplus" is illustrated in Figure 2.5, where two of the individual's indifference curves showing the trade-off between all other goods, represented by income, and some good X are presented as I1 and I2.

Let us assume an individual is at point A consuming zero units of X. This might occur because the good does not exist or is priced at such a

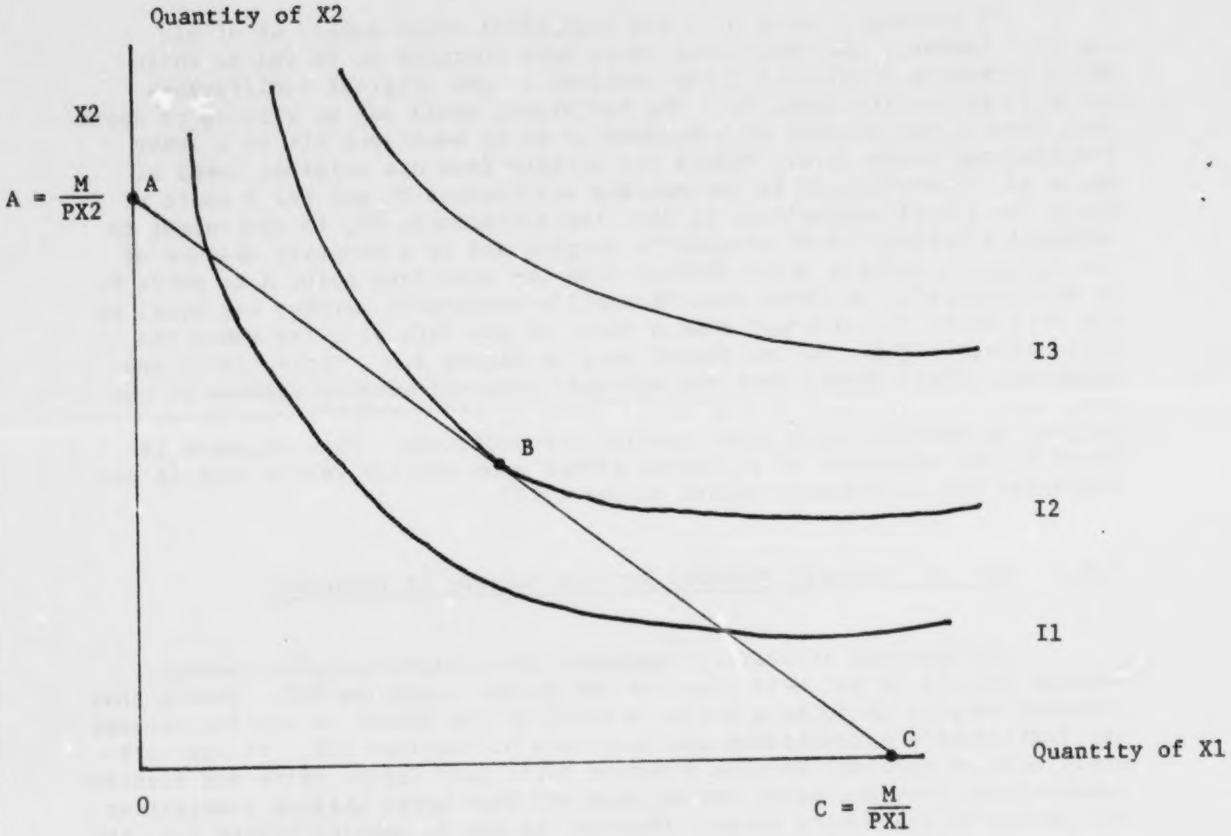


Figure 2.4

Indifference Map of X1, X2

high price, such as PA, that the consumer chooses to consumer zero units of X. If X is introduced at some price PX, income M yields the budget line AZ. Point E is then the utility maximizing point for the individual, because it is on the highest utility level obtainable given income M and price PX. Thus, at price PX the individual would choose to consume Q units of X causing utility to increase from U1 to U2.

To consume Q units of X the individual would expend AB of his income. However, the individual could have foregone AC in income while still consuming Q units of X and remained on the original indifference curve I1 at utility level U1. The individual would not be willing to spend more than AC for Q units of X because to do so would put him on a lower indifference curve (i.e., reduce his utility from his original level at point A). Therefore AC is the maximum willingness to pay for Q units of X while the actual expenditure is AB. The difference, BC, is equivalent to Marshall's definition of consumer's surplus and is a monetary measure of the change in utility value derived from the move from point A to point E. It was originally believed that Marshall's consumer's surplus was equal to the area under the ordinary demand curve to the left of Q and above the price line, as shown by the shaded area in Figure 2.6. Hicks (1941) and Henderson (1941) showed that the ordinary consumer surplus measure of the area under the ordinary demand curve would equal consumer's surplus as defined by Marshall only under special circumstances. This argument is based on the existence of an income effect upon utility levels that is not accounted for in ordinary demand curves (ODC).

2.2.2 Why the Ordinary Consumer Surplus Measure is Incorrect

OCS does not accurately represent the consumer surplus concept because utility is not held constant for points along the ODC. Recall that consumer surplus is to be a dollar measure of the change in utility because the individual's expenditures are less than his maximum WTP. To appropriately measure consumer surplus a demand curve must depict price and quantity combinations that represent the maximum WTP that keeps utility constant at all points in the demand curve. However, as can be seen on Figure 2.5, the consumer equilibrium price quantity combinations represented at point A and point E and used to plot points A and E on the demand curve in Figure 2.6 are not at the same level of utility. In general, the level of utility corresponding to points on the ODC increases moving down the curve. The OCS measure is not true consumer surplus because it measures the differences between expenditures and the maximum WTP to remain at the same level of utility plus the change in WTP due to the change in utility. This latter effect is what is known as the income effect.

Recognizing these problems, Hicks (1944) developed an alternative demand curve called the income compensated demand curve (ICDC) and several alternative consumer surplus measures. Whereas the ODC gives the quantity that a utility maximizing consumer with a given income level will demand at each price, the ICDC shows the quantity a consumer will demand at each

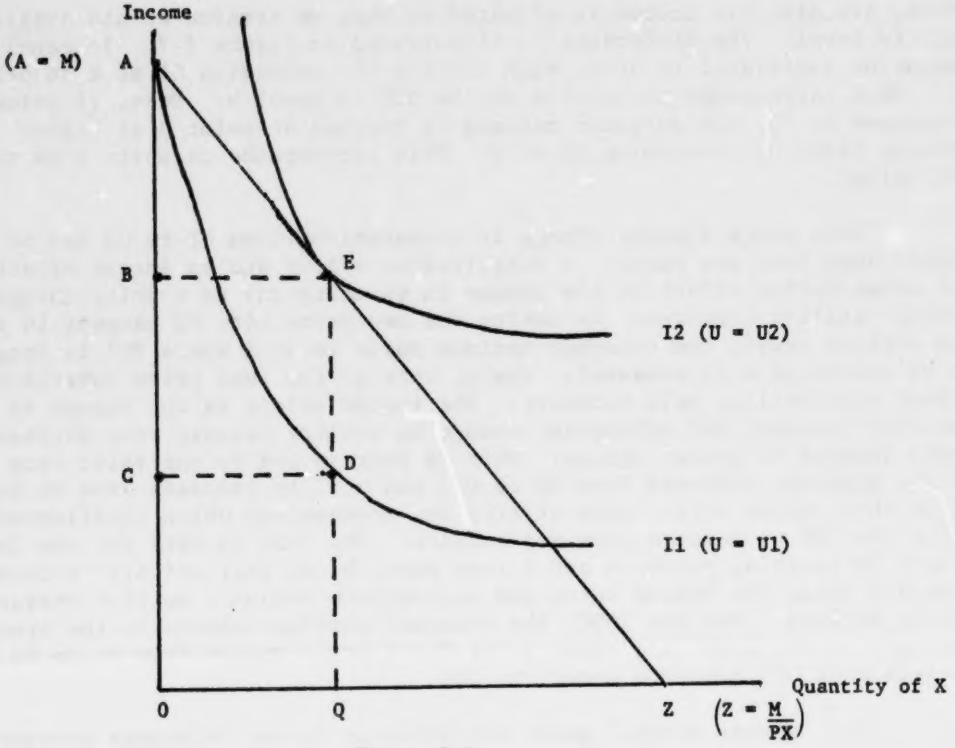

Income
(A = M)
A
B
E
C
D
I2 (U = U2)
I1 (U = U1)
0
Q
Z
Quantity of X
(Z = M/PX)

Figure 2.5

Marshall's Consumer Surplus

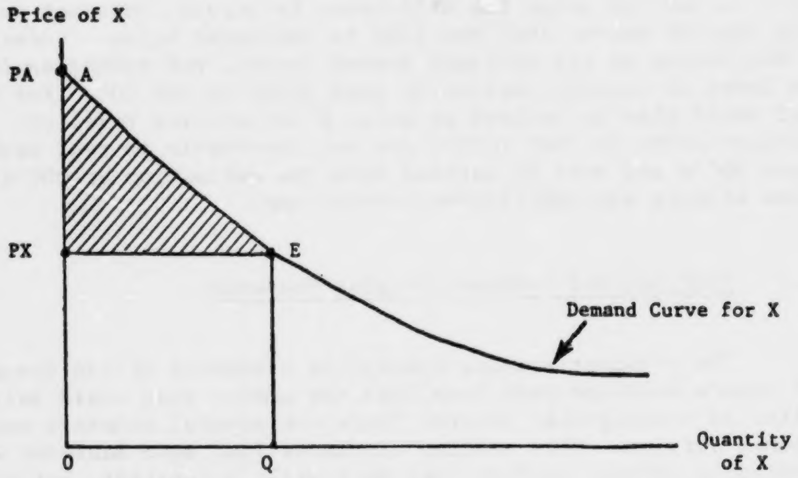

Price of X
PA
A
PX
E
Demand Curve for X
0
Q
Quantity of X

Figure 2.6

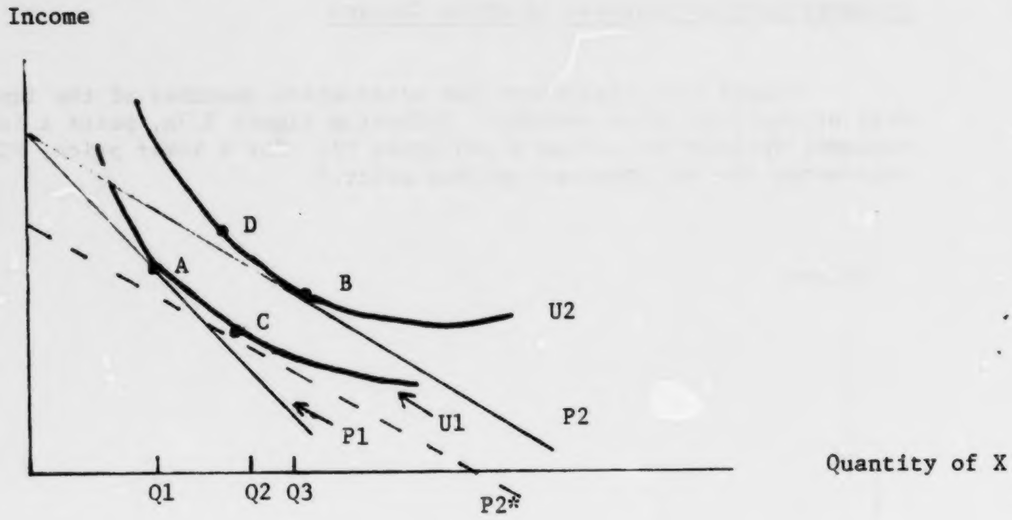
Ordinary Consumer Surplus Using Ordinary Demand Curves price, assuming his income is adjusted so that he remains at his original utility level. The difference is illustrated in Figure 2.7. In panel a, assume an individual is at A, with utility U1, consuming Q1 of X at price P1. This corresponds to point A on the ODC in panel b. Next, if price is decreased to P2, the consumer maximum is reached at point B at higher utility level U2, consuming Q3 of X. This corresponds to point B on the ODC below.

This price induced change in consumptions from Q1 to Q3 can be broken down into two parts: a substitution effect and an income effect. The substitution effect is the change in quantity due to a price change holding utility constant. By making the new price line P2 tangent to the old utility level, the consumer optimum point is at C where P2* is tangent to U1 and Q2 of X is consumed. Again, this is the pure price substitution effect with utility held constant. The income effect is the change in the quantity consumed and subsequent change in utility because real purchasing power changes as prices change. This is represented by the shift from P2* to P2, quantity increase from Q2 to Q3, and utility increase from U1 to U2. It is this income effect upon utility and consumption which invalidates using the ODC to measure consumer surplus. The ICDC adjusts for the income effect by plotting points A and C (see panel b) so that utility is held constant along the demand curve and appropriate consumer surplus measures can be derived. For the ICDC1 the consumer surplus measure is the area to the left of the ICDC1 and above price for a price change from P1 to P2 and is less than OCS measured under the ODC.

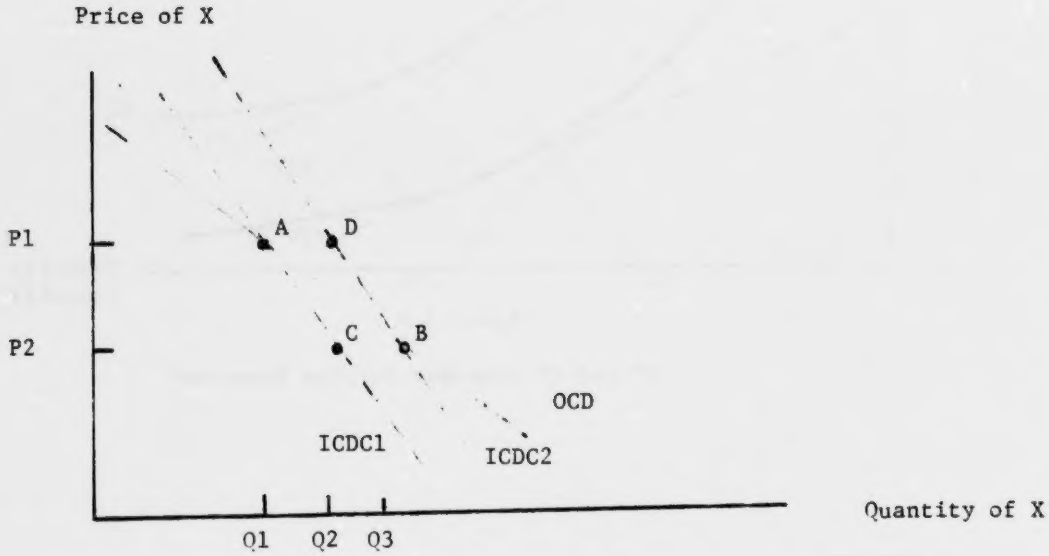
For "normal goods," goods for which as income increases consumption of the good also increases, the ICDC will be steeper than the ODC. Where there are no income effects, i.e., changes in income do not affect consumption levels, the ICDC equals the ODC. The question of how large the income effect is and how large the difference is between consumer surplus measures using the ODC rather than the ICDC is addressed below. Unfortunately ICDC's are not unique as are ordinary demand curves, but rather an ICDC exists for each level of utility implied by each point on the ODC. For example, an ICDC2 could also be derived at point B for utility level U2. Another important point is that ICDC's are not observable in real market situations as are ODC's and must be derived from the estimation of ODC's, estimated income effects and restrictive assumptions.

2.2.3 Four Refined Consumer Surplus Measures

The consumer surplus concept of a measure of the change in utility that occurs when one pays less than the amount that would maintain constant utility is unambiguous; whereas there are several monetary measures of consumer surplus. This section discusses four more measures which are technically correct in that they hold utility constant, but which differ in terms of which utility level is used for comparison and if the individual can affect the quantity consumed.


Income
D
A
B
C
U2
U1
P1
P2
Quantity of X
Q1
Q2
Q3
P2*

Panel a: Utility Map


Price of X
P1
P2
A
D
C
B
OCD
ICDC1
ICDC2
Quantity of X
Q1
Q2
Q3

Panel b: Demand Curves

Figure 2.7

Derivation Of Ordinary And Income Compensated Demand Curves

Consumer Surplus Measures of Price Changes

Figure 2.8 illustrates two alternative measures of the impact of real or implicit price changes. Following Figure 2.7a, point A is the consumer optimum for income M and price P1. For a lower price, P2, point B represents the new consumer optimum point.[3]

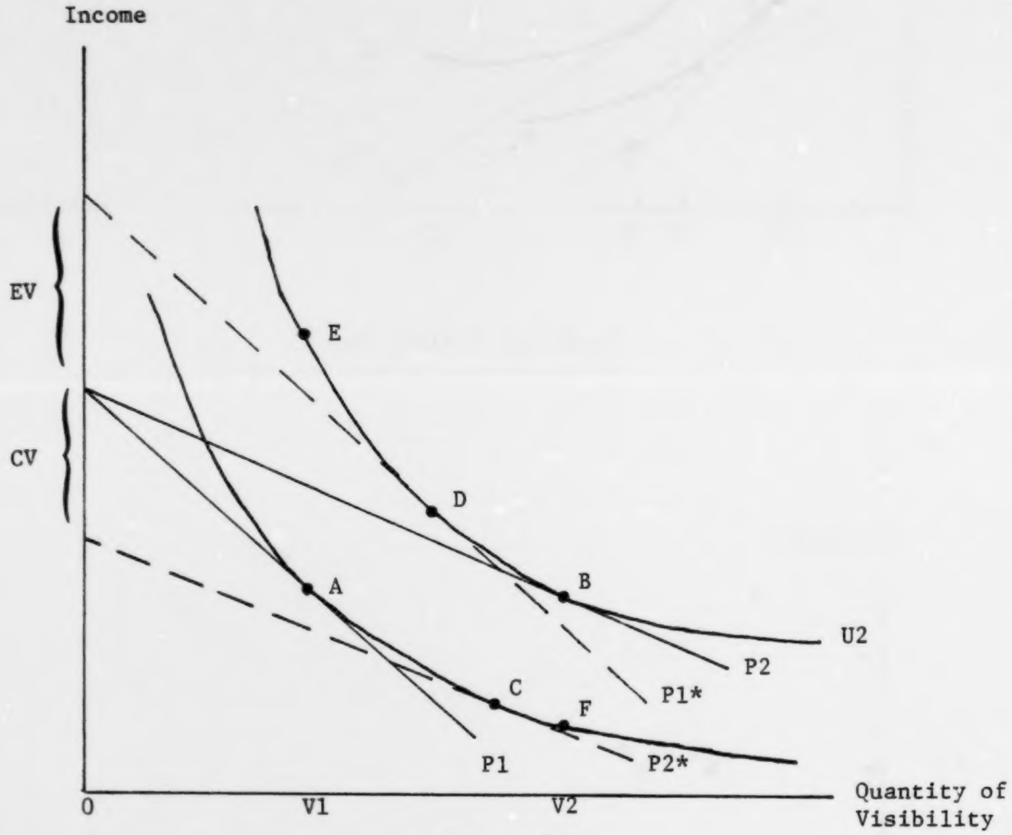

Income
EV
CV
E
D
A
B
C
F
U2
P2
P1*
P1
P2*
0
V1
V2
Quantity of Visibility

Figure 2.8

EV and CV Consumer Surplus Measures

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[3] These definitions and presentations can be generalized to multiple price changes. See Layard and Walters (1978).

Two monetary measures of this change in utility from U1 at point A to U2 at point B are "compensating variation" and "equivalent variation."

1. Compensating variation (CV) is the change in income, given the new price, which offsets the change in utility induced by the price change if the individual is able to vary the quantity consumed. Given the new P2, income equalling CV could be withdrawn and the individual would substitute consumption to achieve maximum utility at the original level U1 at point C.

2. Equivalent variation (EV) is the change in income, given the old price, which yields the same change in utility as the price change if the individual is able to vary the quantity consumed. Given the old price P1, income equalling EV could have been given to the individual and by substituting consumption, utility level U2 would be reached at point D.

As long as the income effect is non-zero, EV and CV measures will not equal each other or OCS. It has been demonstrated by many authors (Hicks 1944; Patinkin 1963; and Freeman 1979a) that the CV and EV measures are equivalent to the area under income compensated demand curves. In general, EV is measured by change in the area under the ICDC that corresponds to the new level of utility and CV is measured by changes in the area under the ICDC that corresponds to the original utility level. In Figure 2.7b for a price change from P1 to P2, CV is measured using ICDC1 and EV using ICDC2. It is readily observable that for a price decrease the equivalent variation exceeds the compensating variation measures if Q is a normal good. This is due to the income effect.

A positive income effect implies that as real income increases the marginal WTP for additional units of the good increases. For example, as income increases, the marginal WTP for increased air quality may also increase. For the higher level of utility, U2, represented in ICDC2, the real income is larger than for utility level U1 represented in ICDC2. Therefore the maximum WTP for changes in air quality based upon utility level U2 is larger than the maximum WTP based upon U1. Consumer surplus, as the difference between this maximum WTP and expenditure is therefore larger when based upon U2 (EV measure for a price decrease) than when based upon U1 (CV measure for a price decrease). For the OCS measure, utility varies from U1 to U2. Consequently, the OCS measure is between the EV and CV measures.

Consumer Surplus Measures of Quantity Changes

The individual is not always able to choose the quantity consumed. This is particularly true for air quality at a particular site. The air quality at a national park is seldom under the influence of any one individual the day he recreates there. Two measures--"compensating suplus" and "equivalent surplus"--are applicable in cases where quantity of the good cannot be adjusted regardless of whether there are any market prices.

1. Compensating surplus (CS) is the change in income that offsets the change in utility induced by the change in the quantity of the good. The individual is at the new quantity level and old utility level.

2. Equivalent surplus (ES) is the change in income that yields the same change in utility as did the change in the quantity of the good. The individual is at the old quantity level and the new utility level.

CS and ES are illustrated in Figure 2.9 for an increase in visibility from V1 to V2, where income represents an aggregate of all market goods and U1 and U2 are indifference curves. ES equals the addition to income that at the original visibility level would yield a utility change equivalent to the visibility quality improvement. The CS measure equals the reduction in income necessary to return the individual to the original utility level at the new visibility level. It is again the amount of income that offsets the utility change caused by the change in visibility while the individual remains at the new visibility level.

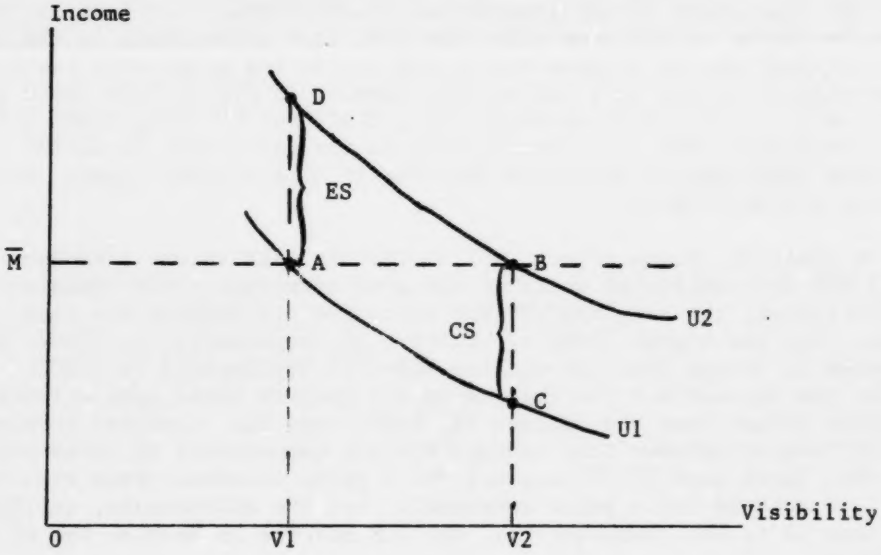

Figure 2.9

CS and ES Consumer Surplus Measure

CS and ES could also be depicted in Figure 2.8 as the distances BF and AE, respectively. These measures will also be of different magnitudes, which again depends upon the size of the income effect.[4]

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[4] Freeman (1979a) has suggested that when the ability to substitute is not present, which distinguishes the CV and EV measures from the CS and ES measures, CV and EV measures logically reduce to the CS and ES measures shown on Figure 2.9.

2.2.4 Comparisons Among the Consumer Surplus Measures

Ordinary consumer surplus and the four refined measures can also be compared in terms of their relative size, their implied reference level of welfare, and other more technical aspects.

Size

If there are no income effects, or if changes in real income do not affect consumption levels of the good in question, then all measures are equal. If, however, the commodity is a normal good (positive income effect), then for a price decrease we have:

$$ES > EV > CV > CS$$

For a quantity increase we have:

$$ES > CS.$$

By examination of the definitions it can be shown that the compensating and equivalent measures are symetrical. In other words, CV for a price decrease is equal to EV for a comparable price increase; and CS for a quantity decrease is equal to ES for a comparable quantity increase. Therefore, for a price increase of a normal good, we have:

$$CS > CV > EV > ES$$

and for a quantity decrease:

$$CS > ES.$$

The issue, then, is how large the differences are between each of the refined measures and OCS. Generally the OCS lies somewhere between the EV and CV measures for any particular price or quantity change (the OCS measure does not apply as directly for quantity changes). In some cases the OCS measure is a close approximation of the other measures, as shown by Willig (1976) and by Randall and Stoll (1980).

Willig (1976) first addressed this issue for changes in prices and found that OCS yields a satisfactory estimate of the welfare change unless the income effect is very large, expenditures on the good are a large component of income, and the price or quality change is large. In fact, the error in approximation is probably much smaller than the error in estimation of most demand curves for visibility.

To illustrate the size differences between OCS and either EV or CV measures Willig provides the following formula, where the income elasticity of demand equals the percent change in quantity demanded for each one percent increase in income:

$$\frac{OCS - Wp}{OCS} \approx \frac{OCS*N}{2M}$$

Wp = EV or CV as appropriate

OCS = ordinary consumers surplus

N = income elasticity of demand

M = initial level of income

As an example, if income elasticity = 1.1, and $\frac{OCS}{2M} = \frac{\$500}{\$20,000} = .25$ then the percent error in using ordinary consumer surplus is 2.75 percent. This holds quite closely if $\frac{OCS * N}{2M} \leq .04$. Exact formulas are also provided for other, more general cases.

Blocksteal and McConnell (1980) point out that Willig's formula is very limited for cases where the choice is between unalterable quantity levels (perhaps large "all or nothing" choices), as is often the case for changes in the environment. In these cases the large changes will further increase the size differences of the measures due to substantial nonlinearities not accounted for in Willig's calculations. The calculations are also limited when demand cannot be obtained from observable data. In these instances the authors argue that the appropriate measurement of the impacts would be made with the CS and ES measures.

Randall and Stoll (1980) undertook an analysis similar to Willig's for changes in quantities using ES and CS measures. The results are very similar for small changes in quantities; but where changes are large, the good is highly valued, and where income elasticity of WTP is large, the differences are likely to be substantial. Willig's formulation can be used for this analysis by substitution of Wp for ES or CS; and N = income elasticity of WTP (see Randall and Stoll 1980, page 454); however, the authors support Blocksteal and McConnell by suggesting that these formulas underestimate the difference in size of the measures for large quantity changes.

Reference Level of Welfare

Let us concentrate upon the ES and CS measures for changes in visibility. The CS measure tells what compensating change in income is necessary to make the individual indifferent between the original environmental quality and the new situation. Regardless of the direction of change, the CS measure takes the original utility point as the basis of comparison. In this sense it also implies that the individual has what has become known as property rights to the initial level of visibility.

The ES measure tells what income payment would lead to the same utility change as the change in visibility. In other words, ES is the amount of additional income necessary to induce the individual to forego an increase in visibility *or* the amount of income taken from the individual to yield an equivalent utility change as a visibility degradation. Therefore the ES measure takes the new or proposed position as the reference level of utility, and implicitly vests the individual with the property rights level associated with the new or proposed visibility levels.

From a theoretical standpoint the choice of ES or CS measures primarily depends upon the choice of an appropriate reference level of utility, however; the implied property right aspect of the comparison among the measures greatly affects the application of the welfare measures to actual changes in visibility and must be considered. Section 4.2.2 below examines this issue and the appropriate choice of measures in more detail.

In the marketplace the individual is a price taker and has no designated right to any particular set of prices. For example, if a price change were to occur, the correct measure of value would be based upon the existing situation and therefore would be the compensating variation measure (see NUREG 1980). However, in situations where other rights have been established, such as legally mandated lower rents for low-income housing, the equivalent variation measure would be appropriate.

For visibility the establishment of property rights is not clear cut. Individuals may believe that they have the property rights to different levels of visibility. Further, if no rights are assigned, the state that the individual desires will often determine the appropriate surplus measure. For example, advocates of the proposed new level (of visibility) may believe that level to be the appropriate property rights allocation. For this group the equivalent variation measures are appropriate. On the other hand, dissenters to the change may believe the current level is appropriate; consequently, the compensating measures are appropriate for this group.

Other Points of Comparison

Other points of comparison have also been thoroughly examined. These include the concepts that the EV measure relates to the new utility level for proposed changes and consequently is more in keeping with conceptual welfare measures of a proposed change than the CV concept of preventing a change (Silberberg 1972); that if multiple sequential changes are proposed the EV measure is not independent of the order in which changes are considered, except under special assumptions, while the CV measure is (Silberberg 1972); and that the EV measure does yield rankings of multiple alternatives that are consistent with the underlying utility preferences while the CV measure may not (Hause 1975 and Freeman 1979).

Selection of the Appropriate Measure

The points of comparison discussed support the refined measures over the OCS measure as monetary measures of benefits associated with a change in the quantity or implicit price of visibility. However, the fact that the measures are, in certain circumstances, approximately equivalent theoretically often justifies the use of whatever measure is most readily and accurately available. Where there are large price or quantity changes, or where WTP is very responsive to income changes, the refined measures should be used. CS and ES measures should be used where the individual cannot affect the quantity consumed; otherwise the CV and EV measures are appropriate. The selection of CV and CS versus EV and ES measures is not clear cut and must be determined based upon how the benefit measures are to be used. Because several techniques used to estimate monetary benefit measures have specific implications about property rights this criteria may dominate other considerations when choosing an appropriate measure. This point is discussed in more detail in Section 4.2.

2.3 Aggregation to Total Benefit Measures

Benefit-cost analysis is based upon the proposition that if the total benefits of a proposed change exceed total costs, the project is an economically efficient reallocation of society's resources. Thus far, this chapter has focused only on monetary measures of benefits of air quality changes for an individual. Because air quality is a public good where changes affect many individuals, the appropriate total benefit measure is some combination of benefits for all individuals affected by the proposed change. The problem is to identify all potential benefits and affected individuals and how their benefits are to be aggregated to a total or weighted for comparisons. The number and type of individuals affected will depend on the location, frequency and timing of the air quality impact. For example, a permanent urban plume would affect all the residents and visitors in the urban area whereas a prescribed burn that occurs one week out of the year affects only those who are present at that time.

There are many types of benefits from air quality control, including prevention of agricultural and materials damage, health impacts and aesthetics impacts. This guidebook concentrates on the latter, within which activity values, option values, and existence values should all be considered. The types of value being examined determine the affected population. "Activity value" applies to residents of and tourists to the location where the change will occur, "option value" applies to all individuals who could reside at or visit the location, and "existence value" applies to all individuals. Usually the largest set of individuals for whom benefits are measured are those for whom benefits could potentially be captured. For example, all activity value benefits could potentially be captured through taxes, entrance fees, and the like. Option and existence value benefits could potentially be captured for all individuals of the same country through taxation, which could then be used to pay the costs of a program. Option and existence values for citizens of foreign countries are unlikely to be captured and are usually not considered for projects which do not cross international boundaries.

The selection of the appropriate methodologies to aggregate and compare benefits across individuals and through time is a difficult problem. Different methodologies can result in variations in the total benefit measures far outweighing variations from selecting alternative benefit measures. Because these methodologies are not the focus of this guidebook and are extensively addressed elsewhere, the next sections highlight problems in aggregating and comparing benefits, suggest directions that can be taken, and provide references for additional reading.[5]

2.3.1 Aggregation Across Individuals

The first problem that must be addressed is how to compare and aggregate all the individual benefits which occur in the same time period; this is the aggregation to obtain total yearly benefits. A frequent practice in benefit-cost analysis is to simply sum the benefits across all affected individuals. The advantage of this approach is that if total benefits exceed total costs there is a potential net improvement in the monetary measure of society's well-being, which will yield what is called an efficient reallocation of society's resources. This is because one version of what is called a pareto optimal change could occur: that is, some benefits could be taxed away and redistributed to cover damages and costs so that some individuals are better off and no individuals are worse off. A problem with this efficiency criterion is that the system of taxing benefits to pay costs may be impossible to implement on a project-by-project basis, resulting in an unequal distribution of impacts. On the other hand, because the federal government undertakes a large number of projects, each of which may have positive or adverse impacts to any individual, varying impacts from project to project may balance the distributional inequities of any one project (see Freeman 1979a; Polinsky 1972; and Freeman and Haveman 1977 for additional discussions).

There are several shortcomings to this simple aggregation approach. Any aggregation is an implicit weighting of benefits. Simple aggregation implies that one dollar of benefits or damages is of equal importance to all individuals regardless of income or location.

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[5] Useful discussions on the concepts and methods of aggregating benefits may be found in Sassone and Schaffer 1970; Mishan 1972; Freeman 1979a; Mikesell 1977; and Lind, et al. 1982.

Another problem with simple aggregation is that measured WTP by lower-income individuals is likely to be less than that of higher-income individuals. This is because the greater financial flexibility of the latter group may yield a lower marginal utility of money and increased willingness (and ability) to pay. In this situation a simple aggregation of benefits tends to support more projects which provide disproportionately greater benefits to higher-income groups. Because the use and enjoyment of environmental quality, such as visibility, in urban and recreation settings is often not income constrained, the simple aggregation of WTP measures may lead to inequities in the distribution of benefits.

An example of the equity issue is a case in which a high-income individual (say $100,000) receives an economic benefit of $1,100 which exceeds damages of $100 each to 10 lower-income individuals. While a tax of $1,000 of the benefits could cover the damages, this may not be a politically and socially acceptable action. Hence, the distribution of impacts of a proposed project cannot be ignored.

The same concern holds for locational distribution of impacts. For example, the Rocky Mountain West is faced with potential environmental degradation because the benefits of energy independence and potentially lower energy costs to the rest of the country may exceed the local damages. Another example is the issue of whether an individual should be restrained from developing a tract of private land because it may spoil the view from a national park used by many citizens across the country. In both cases the incidence of benefits and damages fall upon different groups of people at different locations.

Technically, what is needed to appropriately compare the distributional impacts of benefits is an acceptable weighting scheme, which is often a political rather than an economic issue. One approach which has been accepted in some instances is the system of multiple objectives and accounts established by the Water Resource Council's Principles and Standards (1979), which displays benefits and damages by categories of "region" and "rest of nation" and specifically separates out impacts to low-income, unemployed or minority individuals. With this approach the simple aggregate benefit measure may be more meaningfully evaluated.

2.3.2 Aggregation Across Time

Once benefits are aggregated to yearly totals, these totals must be aggregated through time. The standard procedure is to discount future benefits to a present value following the logic that a dollar held now is worth more than a dollar to be held sometime in the future.

The choice of the appropriate discount rate is a complex and often unresolved issue.[6] In practice the choice of a discount rate is usually from among a set of prevailing market rates for financial instruments of duration equal to the project length, for 50 years, or for some other predetermined rate. This rate represents an intertemporal weighting scheme and can greatly affect the aggregate benefit measure. Table 2.1 shows the total present value of a constant stream of $1,000 in benefits per year for alternative combinations of discount rates and time horizons. These data show that the choice of discount rates and time horizons can radically affect the total benefit measure and overwhelm the measurement problems in the individual value measures.

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[6] Useful in-depth discussions can be found in Mikesell 1977; Lind, et al. 1982; Mishan 1971; and Sassone and Schaffer 1978. Other readings of interest include Baumol and Oates 1979; Sandler and Smith 1976, 1977; Arrow and Fisher 1974; and Krutilla, et al. 1972.

Table 2.1: Present Value of $1,000 Benefits Per Year

	Discount Rate			
Years	0	5	10	15
25	$25,000	$14,094	$9,077	$6,460
35	$35,000	$16,374	$9,644	$6,617
50	$50,000	$18,256	$9,915	$6,661
75	$75,000	$19,485	$9,992	$6,664

The choice of discount rates is further complicated by population growth, which must be accounted for in either the yearly benefit figure or the discount rate, by inflation rates, and by changes in prevailing market interest rates over time. Particular care must be taken to account for the effects of inflation. Either all benefits should be expressed in real (inflation adjusted) dollars for each year and a real discount rate used, or all benefits should be expressed in nominal dollars with a nominal, usually market, discount rate used. Exact formulation can be found in Mikesell (1977).

Discounting procedures are explicit intertemporal weighting schemes subject to a great deal of uncertainty about future generations. Should impacts to future generations be weighed (discounted) to lower values than current impacts? Will future generations have the same, or similar valuations of impacts? Future tastes and preferences, income distributions and the degree of aversion to risk are all unknown, but discounting procedures implicitly project current values as expected future values. If individuals are risk averse, and possibly in other circumstances, it has been shown that the discounting procedure, with the use of expected future values, biases decision making toward accepting development rather than conservation. In essence, the problem is that the future wishes are unknown while the current generation has the power in the decision-making process.

The problem of intertemporal choice and allocation of resources is the most critical and difficult where a change is irreversible or a resource is irreplaceable. Few things are totally irreversible with unlimited economic and political resources, but many things are effectively irreversible. For example, mineral extraction from pristine environments, flooding of canyons, and the demolition of historic buildings are all examples of actions which cannot normally be reversed. Due to natural chemical processes, wind, and gravity, most air pollution problems can be rectified if the source is controlled; however, the effects of the pollutant may be irreversible. For example, exposure to asbestos is apparently linked to higher rates of cancer and mortality long after the source is removed.

In summary, there is no discount rate which is appropriate for all instances, although in many cases there are required discount rates for federal projects. Where possible, the discount rate selection should be a policy decision. If an appropriate rate is not available, it is advisable to present total benefits using several alternative rates so the effect of alternative rates can be ascertained.

2.4 Technical Consumer Behavior Models and Assumptions Used to Derive Consumer Surplus Measures

Demand curves and consumer surplus measures may be theoretically derived through the use of several alternative mathematical constructs and assumptions about consumer behavior. This section introduces several alternative constructs that are used by researchers to model the economic benefits of changes in air quality. While the technical researcher will need to be familiar with these models of consumer behavior, others need not be familiar with this material to obtain an overview of how visibility benefit analyses are conducted.

A Simple Utility Map Approach

In general, an individual tries to maximize his utility subject to constraints. In the case of visual quality, one constraint may be the inability to alter the level of quality that is incurred. By using income as the composite index for all other goods, we may specify utility as a simple function of visual quality Q and income M, where $\overline{M}$ is the initial income level for the individual:

$$U = U(Q, \overline{M}) \quad (1)$$

If one considers an improvement in visual quality from state QA to state QB, the surplus measures are defined as follows:

$$U(QA,\overline{M}) = U(QB,\overline{M} - CSAB) = U0 \quad (2)$$

$$U(QB,\overline{M}) = U(QA,\overline{M} + ESAB) = U1 \quad (3)$$

where U0 is the original utility level and U1 is a higher level of utility obtained as visual quality is improved as depicted in Figure 2.9 on page 2-18. CSAB and ESAB are the CS and ES measures for a change from QA to QB. For a decrease in visual quality from state QA to state QC one may define the measures as follows:

$$U(QC,\overline{M}) = U(QA,\overline{M} - ESAC) = U2 \tag{4}$$

$$U(QA,\overline{M}) = U(QC,\overline{M} + CSAC) = U0 \tag{5}$$

where U2 is less than U0. If the exact utility map specification is known or assumed one can derive the functional form of the ES and CS functions. For example, as presented in Rowe et al. (1980a), if:

$$u = aVi + b{*}Vi{*}M + C{*}M * \Sigma di{*}Xi{*}Vi + \; fi{*}Xi$$

where Vi represents the ith visibility level, Xi is the ith socioeconomic variable, M is income and a, b, c, di and fi are parameters, the ES and CS functions can be derived for a proposed visibility decrease from V1 to V2. For example:

$$ES = \frac{(V_1 - V_2)\ (a + b{*}M + \Sigma di+Xi)}{V_1{*}b + c} \tag{7}$$

Drawbacks to this approach are that the specification of the surplus functions is contingent upon specifications of the utility function, which is unknown, and that the individual is seen as not being able to take mitigating actions to incur visibility levels other than the current level. If, however, the individual does take mitigating actions that allow him to choose the visibility level he will incur, EV and CV measures would be correct and this simplified approach would not be appropriate. The benefit of this approach is its simplicity and guidance as to the likely determinants of the ES and CS values.

Household Production Function Approach[7]

This approach draws upon the work of Lancaster (1966), Becker (1965), Muellbauer (1974), Muth (1966), and Pollack and Wachter (1975). It is based on the assumption that the individual does not derive utility directly from the consumption of commodities and environmental goods, as in the standard utility approach, but rather from outputs and experiences that are produced through a household production process that combines the market and non-market commodities as inputs. In this sense, visibility is not valued in and of itself but rather for how changes in the level of Q affect the desired experience. For example, air quality at alternative recreation sites will affect the value to the individual of recreation at each site and will therefore affect recreation demand at each site.

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[7] A good explanation of the current work in this area is found in Eubanks and Brookshire (1980).

In the simple case where time constraints are not considered, the model may be written as:

$$\text{maximize} \quad U(Z_1, Z_2 \ldots, Z_n)$$

$$\text{subject to} \quad F(Z_1, Z_2 \ldots, Z_n; X_1 X_2, \ldots, X_m, Q) = 0$$

$$M = \sum_{i=1}^{m} P_i X_i$$

where:

Z_j = the jth output or experience, $j = 1,2,\ldots,n$

X_i = ith market input good, 1, $= 1,2,\ldots,m$

P_i = the price of ith market input, $i = 1,2,\ldots,m$

Q = an environmental good

M = the individual's fixed income

$U(\cdot)$ = the individual's utility function

$F(\cdot)$ = the individual's transformation function, which summarizes the household technology to produce the Z_i's from X_i's

and where the utility and transformation functions are assumed to have classic properties. The individual's problem is to choose the levels of final outputs and experiences he desires and the subsequent mix of input goods and visibility to produce the outputs given market prices and the household production technololgy. The individual must therefore maximize utility from the produced goods and experiences and simultaneously minimize input costs to produce these final goods and experiences from the market inputs and the environmental good. This maximization/minimization problem can be solved to yield demand function for the output goods and experiences.

$$Z_i = Z_i \ (P_1, P_2, \ldots, P_n, Q, M)$$

By analyzing the effects of Q on the derived demand function for Zi, EV and CV measures for each change in Q can be derived. The introduction of time constraints can only be made at the cost of more complicated mathematics and implementation requirements.

In their analysis of the impact of congestion upon recreation demand, Cicchetti and Smith (1976) note that without specific information on the forms of the utility function and consumer production technology, it is impossible to distinguish operationally between a standard utility framework and the household production framework in terms of testable hypotheses. Each of the models generates the result that there is a positive willingness to pay for air quality increases due to associated utility increases. Without assuming specific functional forms or without obtaining empirical information about consumer production technology, nothing more can be said about this relationship.

Expenditure Function Approach[8]

The utility maximization problem for the individual may be conventionally expressed as:

$$\text{maximize} \quad U = U(X)$$

$$\text{subject to} \quad \sum_{i=1}^{N} PiXi = M$$

where X is the vector of quantities of goals and services (X = X1, . . ., Xi, . . .,Xn), P is a vector of prices (P = P1,P2,...,Pn), and M is money income. The solution to this problem leads to a set of ordinary or Marshallian demand functions

$$Xi = Xi(P,M) \text{ for } i = 1,i...,N$$

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[8] See Maler (1974) for the development of the expenditure function as it relates to the welfare effects for changes in environmental quality and Diamond and McFadden (1974) for applications in public finance. Also see Freeman (1979a) for a slightly expanded version of the material presented in this section.

and some maximum utility level Um. From the ordinary demand function one may derive ordinary consumer surplus measures. The dual of this problem is to:

$$\text{minimize} \quad \sum_{i=1}^{N} PiXi$$

$$\text{subject to} \quad U(X) \geq U0$$

Solving this minimization leads to an expenditure function relating the minimum dollar expenditure necessary, given market prices, to obtain a specified utility level U0:

$$E = E(P,U0)$$

where E is the dollar expenditure, P is the price vector, and U0 is the specified utility level. The solution of this minimization problem yields a set of income compensated demand curves:

$$Xi = Xi\ (P,U0)$$

The utility level chosen for the basis of comparison, which is one of the main considerations in the choice of surplus measures, is specified in the expenditure function. The expenditure function readily explicates the effect of changes in prices on the EV and CV measures. For example, consider a price decrease for visibility, with price P1, from P10 to P11 while all other prices are held constant at P = (P2,P3,...,Pn):

$$CV = E\ (P10,\ P,\ U0) - E\ (P11,\ P,\ U0)$$

$$EV = E\ (P10,\ P,\ U1) - E\ (P11,\ P,\ U1)$$

where U1 is greater than U0 and represents the higher utility level that results from the price decrease.

The advantage of this approach is that if visibility, Q, enters the utility function either directly or indirectly it will also enter the expenditure function. The derivative of the expenditure function, E(P,Q,U0) = M, with respect to Q, with the appropriate change of sign, yields the income compensated inverse demand function or the marginal WTP function, $Eq = \partial E/\partial Q$ for changes in Q. Therefore, for changes in the level of visibility from Q1 to Q2, the Riemann integral of the Eq function yields the appropriate benefit measure:

$$b = -\int_{Q1}^{Q2} Eq\ (P1, Q1, U0)\ dq$$

where b = EV or CV depending upon the choice of U0 or U1.

The disadvantages of this approach are again that the exact form of the expenditure function is contingent upon the form of the unknown utility function. Special restrictions on the interaction of the elements are also necessary to separate and estimate an implicit price for the visibility.

Weak Complementarity

In earlier examples of OCS (Section 2.1.2) and in the previous models of consumer behavior, if a demand curve for some measurable good X, such as recreation days or housing, could be estimated as a function of prices, P, income, M, and environmental quality, Q, as:

$$X = X(P,Q,M)$$

the change in the maximum WTP for X as Q changes could often be used to accurately estimate the maximum willingness to pay function for changes in Q. This is the case when the conditions of weak complementarity hold. Weak complementarity, as defined by Maler (1974) and explicated in Freeman (1979a) involves two conditions: (1) there is some price P2 for which the quantity demanded of X equals zero, and (2) at price P2 expenditures do not change with small changes in environmental quality, or for E = E(P2,P,Q,U0)

$$\partial E / \partial Q = 0$$

Equivalently, changes in Q do not affect utility at price P2 because Q only has value in combination with the consumption of X.

Figure 2.11 demonstrates why weak complementarity is necessary in order to use changes in demand to measure the value of environmental quality. Assume D1 is the estimated demand curve for recreation days at a site with air quality at level Q1 and assume the price remains fixed at P0. The OCS measure is the area ABC. Next, assume air quality increases to Q2, causing the demand for recreation to shift to D2. The benefits of this change can be calculated in three steps:

1. Given the original demand curve, D1, if the price were to increase from P0 to P2, the individual would have to be compensated by income equal to the area ABC to be no worse off.

2. With the condition of weak complementarity, the increase in air quality to Q2 would not affect utility when the price of X is P2 because the consumption of X is zero.

3. Next, let price return to the original level, P0. The individual gains a consumer surplus equal ADE. In order to return to the utility level obtained when the consumption of X was zero, this amount of income would need to be withdrawn. The net effect, or benefit, of the change in Q is therefore the amount of income equalling the area BDEC.

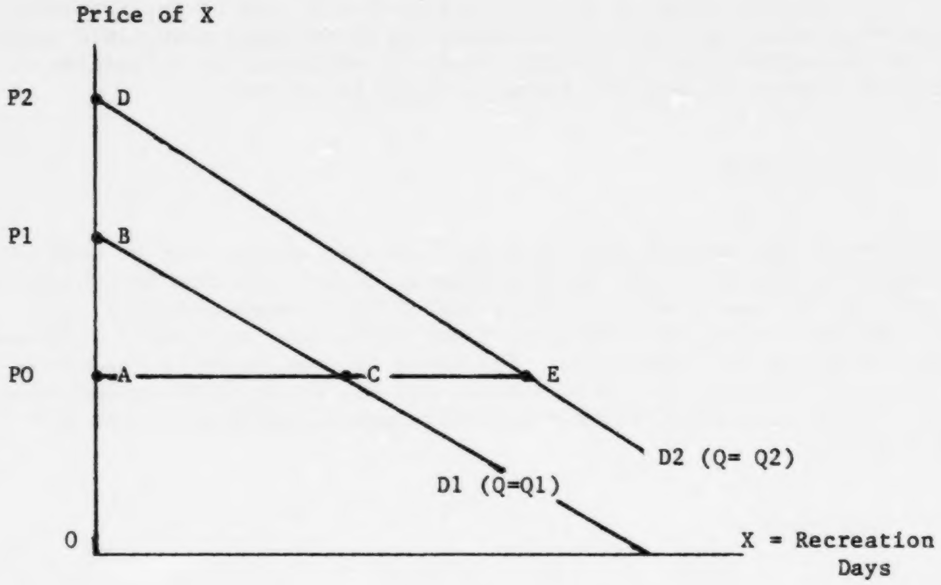

Figure 2.10

Example of Weak Complementarity

As pointed out by Freeman (1979a), with symbols changed for continuity:

> If weak complementarity did not hold, there would be a positive benefit associated with the increase in Q even though the quantity demanded of X were zero in step 2 above. In this case, the area BCED would be an underestimate of the benefits of increasing Q.

If D1 is the Hicks-compensated demand curve, this area (BCDE) is an exact measure of the CV or maximum willingness to pay for the increment to Q. If an expression can be formulated for this area as a function of Q, the derivative of this function with respect to Q is the marginal demand price for Q. Typically, D1 is an ordinary demand curve, not a Hicks-compensated demand curve (page 74).

CHAPTER 3

INTRODUCTION TO VISION THROUGH THE ATMOSPHERE[1]

3.1 The Importance of Atmospheric Science Fundamentals to Visibility Benefits

Everyone would agree that good visibility is desirable, but often the more commonplace the subject, the more difficult it is to think scientifically and quantitatively about it. Some kind of quantitative measure or measures of visibility are absolutely necessary in a benefit analysis. There must also be a known relationship between measures of visibility and human values, on the one hand, and physical environmental factors on the other. Only with this type of knowledge can one determine those parameters to which visibility benefits are sensitive and whether or not they are controllable parts of the environment. For example, would there be any benefit in improving visual range from 100 km to 125 km when the most important view in the area is 50 km distant or when visual range is reduced to less than 10 km by natural fog or rain 70% of the time? Though everyone understands what visibility is, it becomes a difficult and complex topic when put in quantitative terms.

In performing a benefit analysis, the analyst may need to use or to take into account technical information from many diverse areas, such as photographs, visibility monitoring data or model simulations of visibility impacts. It is the purpose of this section to provide a sound, fundamental framework which will allow the analyst to place this information in proper perspective for use in benefit analysis. This framework must span human perception, atmospheric physics and chemistry, optics and air quality meteorology. It is not possible to outline here all the relevant technical information contained in, for example, Protecting Visibility: An EPA Report to Congress (EPA 1979). However, this section will introduce the non-expert to the field.

Visibility impairment analysis is best thought of as a sequential process as outlined in Figure 3-1. Visibility impairment is caused primarily by fine suspended particles and gases which scatter and absorb light. The possible anthropogenic (manmade) sources of these pollutants can be determined by performing an emission inventory. The composition and distribution of these gases and particles is determined by air quality monitoring or can be roughly predicted by air quality modeling. The effect on light viewed by the observer can be monitored by instruments and calculated by established theories. How that light is perceived by the eye is the study of psychophysics. Interpretation of the perceptions are matters

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[1] Sections 3.1-3.7 of this chapter were prepared by Dr. Ronald C. Henry, ERT, Inc., 2625 Townsgate Road, Westlake Village, California 91361.

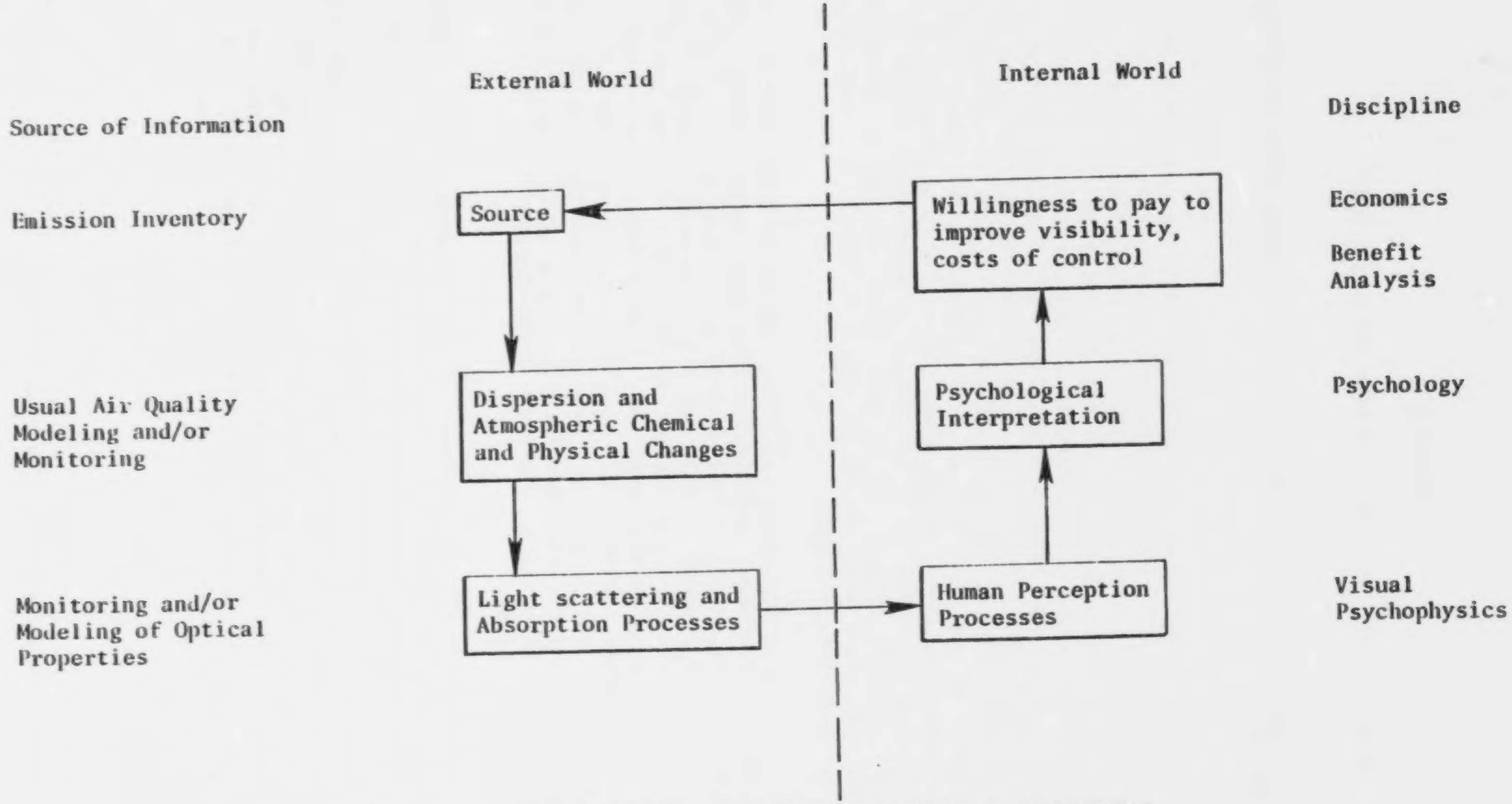
External World
Internal World
Source of Information
Discipline
Emission Inventory
Source
Willingness to pay to improve visibility, costs of control
Economics
Benefit Analysis
Usual Air Quality Modeling and/or Monitoring
Dispersion and Atmospheric Chemical and Physical Changes
Psychological Interpretation
Psychology
Monitoring and/or Modeling of Optical Properties
Light scattering and Absorption Processes
Human Perception Processes
Visual Psychophysics

Figure 3-1. FRAMEWORK FOR UNDERSTANDING VISIBILITY QUESTIONS AND THE CONTEXT FOR THE BENEFIT ANALYSIS

of psychology, sociology and anthropology. The value of the visibility conditions to humans as measured by willingness to pay to obtain improved visibility, is in the domain of economics and visibility benefit analysis. The circle is then closed by decisions of what, if any, sources to control and how to do it.

The remainder of this section gives the analyst an overview of the types of information to be gained and inputs required for each step of the visibility analysis process. In keeping with the current focus of visibility regulations the discussion is, at times, more oriented toward visibility in the context of point source impacts on Class I recreation areas.

Factors Affecting Visibility Impairment

The components of the visibility problem can be classified broadly into physical, perceptual and psychological factors. The physical factors have received by far the most study. Those which must be determined for a visibility analysis include:

- characteristics of source emissions
  - quantities of each type of emitted particles and gases for various sources, i.e., emissions inventory
  - size distribution and chemical composition of emitted particles
  - optical properties of emitted gases and particles
- transport and transformations of source emissions
  - dilution by dispersion and diffusion in the atmoshphere
  - losses by wet and dry deposition
  - formation of particles by chemical reactions, e.g., sulfur dioxide to sulfates, nitrogen oxides to nitrates
  - changes in particle size distributions as pollutants dilute and react
  - effects of relative humidity on particle growth
- optical properties of polluted and pristine atmospheres
  - horizon-sky intensities
  - contrast of plumes and natural objects to the horizon
  - characterization of existing scattering and absorption properties of natural and polluted atmospheres
  - time of day (solar angle)

Perceptual and psychological questions have only recently been the subject of systematic study. Important factors to be considered here are:

- content of the scenic vista
  - size and distance of important objects
  - overall scenic beauty
  - cloud cover--overcast or clear
  - ground cover--snow, rock or vegetation
  - time of day (solar angle)
  - visible sources of pollution
- perceptual thresholds of the human eye-brain system
  - lower limits of detection of visible haze and distant objects
  - relative limits of detection of changes in brightness and color of the horizon sky and objects seen through the air
  - the degree to which texture (fine detail) is visible inside viewed objects
  - the distance to which natural objects are visible (visual range)
- psychological and other factors
  - previous experience and knowledge of the scenic view
  - personal background, sex, age, work experience, education, income level
  - reason for visit to Class I area--biking, boating, hang-gliding, etc.
  - political views

Changes in any or all of these affect the good itself, the context of enjoyment of the good and, thus, valuation of visibility by the observer.

In addition to the EPA Report to Congress cited above, several guidance documents have also been made available and are listed at the end of Chapter 1. These documents should be consulted for detailed information requirements for their respective areas of the visibility analysis. The Monitoring Guidelines and the Workbook are particularly useful sources of general information.

Finally, it should be stressed that the term "visibility impairment" is used as "any humanly perceptible change in visibility (visual range, contrast, coloration) from that which would have existed under natural conditions." (45 FR 80091) Thus, reductions in visibility are not considered visibility impairment unless they are substantial enough to be humanly perceived. Visibility reductions caused by natural sources are not considered impairment whatever their magnitude.

3.2 Human Perception of Visibility

"There is light in shadow and shadow in light, and black in the blue of the sky" (Lucy Larcom, "Black in Blue Sky"). This accurately describes the process of visibility degradation as experienced by an observer. When looking at a dark object (or shadow) light is scattered into the eye by gases and particles in the air and the dark object appears brighter. Conversely, when observing a bright object (or light) its brightness is dimmed by loss of light scattered or absorbed by the atmosphere. The net effect is for all objects near the horizon to eventually blend into the horizon.

In purely descriptive terms, when looking at an object near the horizon through haze, the observer notices that the object or its texture (fine detail) may be obscured or its colors changed; the haze itself may be visible as a dark or light layer which may be colored. Since the effect of haze is for both the object and its background to approach the horizon brightness, the contrast between them decreases, making objects more difficult to see. Thus, haze affects a human observer by changing the brightness of objects, their texture and colors. If conditions are right, one may be able to perceive the haze itself. It may appear as a coherent plume or several visible layers (so called "plume veil") or the haze may be visible as a general or regional haze. The visibility regulations currently emphasize only those cases of impairment which can be unambiguously assigned to a single source. Therefore, the case of a visible plume or plume veil will be of immediate interest.

It is important in this section to reserve the terms "brightness" and "color" for the humanly perceived sensations of lightness and color. This is standard psychophysical terminology (Wyszecki and Stiles 1967). Brightness and color are contents of consciousness and cannot be measured by an instrument. The physical antecedents of brightness and color, which can be objectively measured, are the amount of light energy entering the eye and its distribution among visible wavelengths. A later section will focus on the relationship between perception and their physical antecedents. This section will be devoted to discussion of perceptual clues of visibility impairment in the environment and how they are processed by the eye-brain system. The appropriate results of three recent studies will be heavily relied upon (Malm et al. 1980 a, b; Latimer et al. 1979).

In valuing visibility improvements it is important to understand the effects of perceptual thresholds, content of the scenic vista, and psychological and other factors so that they do not unintentionally affect the valuation (as discussed in Section 2.4). As this topic is less thoroughly discussed in the Report to Congress and other guideline documents, it will receive extended discussion below.

Perceptual Thresholds

A threshold is defined as "a point at which a physiological or psychological effect begins to be produced." (the Merriam-Webster Dictionary.) Without a visibly perceivable effect there can be no benefit measure derived for enhanced visibility aesthetics from changes in air quality (although other benefits, such as health and materials impacts, may occur). Therefore, perception thresholds are basic to the quantification of the good. A later section looks at this question of perceptual thresholds using various visibility indices. At this point, some of the more general aspects of thresholds are noted. Most important is to realize that for perception of visible pollution there are at least three thresholds: absolute thresholds, incremental thresholds and identification thresholds. Absolute thresholds are the limits of perception below which there is no sensation. An example of an absolute threshold is the often used assumption that if the contrast between the sky and a large black object is below 0.02 then the object disappears. A contrast of 0.02 means that the difference between the light intensity coming from the object and the sky is 2% of the intensity coming from the sky. Contrast is especially important because it is contrast in brightness or color that is actually perceived. An absolute threshold for contrast is also called the liminal contrast.

An incremental threshold is linked to the concept of a just-noticeable difference. In this case, we are concerned with the minimum change that can just be noticed. For example, if the contrast of an object on the horizon is 0.20 and a decrease to 0.10 is just noticeable, then its incremental threshold is 10%. This is not an absolute threshold, since the object remains visible. These two types of thresholds are commonly discussed in the psychophysical literature.

A third threshold is unique to air quality studies. This is the level of change necessary to assign a source to the impairment. If a plume is a visible layer, at this point the observer can assign the visual impairment to this observed layer. If conditions are right, he may be able to distinguish the emission source responsible for the plume or haze, e.g., campfires or an industrial plant.

In general, each of these thresholds depends in a complex way on many factors, including the age and experience of the observer, ambient lighting conditions and content of the scene, as discussed below.

Content of the Scene

Some contextual factors that are known to affect perception of visibility are obvious. Size and distance of objects of interest are important, since small objects are harder to see, or have larger thresholds (Blackwell 1946), and the further away they are the greater the intervening mass of the atmosphere. Effects of cloud cover, sky color, ground cover and time of day are less intuitive, but are known to exist. Even less understood is the impact of scenic beauty on the perception of visibility impacts.

Cloud cover can vary from clear skies to dense fog. Obviously, clouds associated with rain or fog will seriously reduce visibility. Less obvious is the potential importance of cloud shadows. These may shade an otherwise bright mountain or make a dark background for the same mountain. Cloud shadows can reduce the light scattered into the eye and increase visibility. Finally, clouds add interest and scenic beauty to most vistas. Two recent studies have found clouds to be an important aspect of the visual environment, Malm et al. (1980a) and Latimer et al. (1980). Both of these studies ask observers to rate the visual air quality of a series of slides of scenic vistas. The Latimer study also ranked scenic beauty. Although they do not report quantitative estimates of cloud cover effects, both reports identify it as important. The Malm et al. report uses cloud cover as a basis for stratifying these data. Similarly, both reports indicate the importance of ground cover, i.e., rock, vegetation, snow, or some combination of these. Whether or not snow is present on a mountain is an important means of classification for Malm et al. (1980a).

The time of day and direction of the sun with respect to the view (solar angle) have been identified as important to the appearance of a scenic vista. Solar angle influences the depth and direction of shadows. Views looking at a small angle from the sun are much influenced by bright forward scattered sunlight.

Psychological and Other Factors

Previous experience or knowledge of a scene can drastically alter ones perception. If a visitor does not know there are any mountains to be seen, then he does not miss them. Thresholds are greatly affected by experience. A mountain may be just visible to an experienced observer who knows just where to look and what to look for, but it may be totally invisible to the casual observer.

Other factors, such as work experience, education, income and political views, potentially influence an observer's view. The Latimer et al. (1980) study compared subjective ratings of Visual Air Quality Index (VAQI) (scale of 1 to 10) of the same 20 slides of western vistas for 13 special interest groups ranging from air pollution professionals and oil company staff to an art class and EPA personnel. An intergroup correlation of 0.48 was the lowest found--between a group of 26 Spanish speaking observers and 12 persons in an art class. Most groups showed correlation of VAQI ratings of 0.8 and above; but there were a number of lower correlations. There does appear to be some indication of important differences, although the Latimer report concludes that there was not any clear-cut case to be made for such differences. This report does claim, however, that the overall scenic beauty of a vista can influence the visual air quality estimates.

The Malm et al. (1980a) report examined the effect of age, education, sex, frequency of visits to National Parks and location of residence on estimates of visual air quality. Again, this study relied on photographic slides. The data consisted of repeated subjective estimates of visual air quality (scale of 1-10) of the same slide projected among other slides. This control slide had a visual air quality index (VAQI) of about 5. There was a mean difference of 0.3 in VAQI rating between men and women. For the number of observations (426 and 305), this is significant at above the 99% level by the usual t-test. Some other differences in visual air quality perception are evidenced between age groups. The 18-24 group rated the control slide significantly higher than the 45-54 age group. On the other hand correlations between demographic groups were 0.98 or higher while within group correlations always exceeded 0.81. Most importantly, all correlations are very high and positive, indicating very good agreement both within and between demographic groups. The researchers conclude that there is not a difference between groups of observers.

To complete this review of current work in the area of human perception of the visual environment, mention must be made of the perceptual studies carried out in Denver, Colorado, by personnel of the National Center for Atmospheric Research (NCAR) and the Institute for Behavioral Science at the University of Colorado. The NCAR study is reported in Mumpower et al. (1980). It is the only recent study that has systematically examined the relative importance of various perceptual clues in the natural environment. This study does not rely on photographs as do the other studies. Ratings of the visual air quality were made along with subjective estimates of several perceptual clues: distance at which objects were visible, clarity of the air, color of the air and existance of a distinct border to the haze. Observations were made by the same individuals several times a day in each of the four directions. These observers elicited perceptual judgments from passers-by, referred to as respondents. The study was carried out in summer and repeated in slightly modified form in winter. In all cases, the perceptual clues which correlated most highly with judgments of subjective visual air quality were subjective clarity of the air and distance to which objects could be seen. Visible haze color and border had more effect in winter than in summer. The correlation between perceptual clues as judged simultaneously by regular observers and passer-by respondents was often very low. This indicates that perceptions of the man-in-the-street are rather different than a trained, experienced observer.

Finally, visibility of texture, i.e., fine detail inside the border of objects, is an important factor in judgment of clarity and distance. Although this factor has not been quantitatively studied as yet, Malm et al. (1980a) and Henry (1979a) hypothesize its potential importance. A group of landscape arhitects for the U.S. Forest Service have also identified texture as important to perception of visibility (Paulson 1979).

Summary

In assessing human perception and its relation to visibility benefits, several important points stand out.

- The limits of perceptions, thresholds, must be defined quantitatively. Thresholds are different for disappearance, noticeable changes, and source assignment.
- Perception of visibility is influenced by the content of the scene, clouds, snow cover, scenic beauty, vegetation, etc.
- There is evidence that estimates of visual air quality from slides does not depend strongly on age, sex, and special interests of the observers.
- Major perceptual clues to judgments of visual air quality in an urban area (Denver) are clarity of the air and the distance to which objects can be seen. The color and noticeable border of the haze are of less importance.

Two major areas of concern to human perception will be treated in other sections. The thresholds of various indices of visibility is discussed in Section 3.4. The importance of adaptation of the visual system to its environment is central to Section 3.6, which discusses various presentations of the visual environment.

3.3 Sources of Visibility Impairment

This section covers sources of visibility reducing components of the air. Natural variations in visibility and their causes will be addressed in Section 3.7 on visibility monitoring. The importance of meteorology and atmospheric chemistry in producing particles from gases is stressed.

Any human activity that produces airborne particles, or gases that can react to form particles, can contribute to visibility impairment. Particles the size of bacteria, 0.1 to 1 micrometers (μm) in diameter, are by far the most efficient on a per unit mass basis in producing visibility impairment. Sources of the colored gas nitrogen dioxide or its chemical percursors are also potential sources of discoloration. In addition, interaction of light and nitrogen dioxide is a key link in the chain of reactions that form photochemical smog and its associated particulates.

Atmospheric chemistry plays a key role in understanding the sources of visibility reduction. The fact is that in most urban and rural areas, the majority of the mass of particles in the efficient light-scattering size range are not directly emitted by a source, but are the product of reactions occurring in the atmosphere involving invisible gases. Secondary particulates are those formed by atmospheric reactions, while primary particulates are those directly emitted by sources. Gaseous emissions which contribute to the production of secondary particles are sulfur oxides, in nitrogen oxides and other organic vapors. Atmospheric reactions can also produce new gaseous species, such as ozone.

The atmospheric chemistry of pollutant gases is extremely complex. For example, concentrations of the red-brown gas nitrogen dioxide are determined in part by the associated concentrations of hydrocarbons, ozone, and nitric oxide, as well as ambient temperature, intensity of sunlight and moisture content of the air. Because the effects of atmospheric dilution add to the complexities of atmospheric chemistry, predicting or modeling of source-receptor relationships for secondary particles and gases is extremely difficult. Unfortunately, the majority of visibility-reducing particles in the air, those in the size range of 0.1 to 1.0 μm diameter, are the product of atmospheric chemical reactions and thus not subject to direct control methods.

Both natural and man-made sources produce primary visibility-reducing particulates and gases which convert to secondary particulates. The natural causes will be discussed later. Table 3.1 summarized sources of pollutants affecting visibility. The major anthropogenic sources of visibility-reducing particulates are combustion sources. Combustion produces primary fine particles, such as coal fly ash or diesel exhaust particultes. Combustion sources also emit reactive gases that convert to particulates in the atmosphere. Also, any high temperature combustion using air will produce some nitrogen oxides, with a certain portion being or becoming nitrogen dioxide. In addition, some industrial process sources produce visibility-reducing particles. For example, primary smelting of ores involves roasting of sulfide ores with resultant large emissions of particles and sulfur oxides.

Agricultural and forestry activity is another major source type. Emissions of soil dust from ground preparation are large but of short range, usually. Application fertilizers and pesticides can affect air quality by adding nitrogen oxides and hydrocarbons to the atmoshphere. An important land management tool is prescribed burning, whereby intentionally ignited fires are allowed to burn under controlled conditions for management objectives, including hazard reduction, forestry and wildlife management, and grazing. Such burning produces emissions of gases and particulates that may cause temporary visibility degradation.

Table 3.1: Manmade Sources of Visibility Reducing Gases and Particles and Their Precursors

Source Type	Examples	Composition of Emissions (in rough order of importance)
Industrial process and stationary combustion	coal-fired power plants, smelters, refiners, synfuel plants	sulfur oxides, nitrogen oxides, primary particulates, hydrocarbons
Mobile sources	autos, diesels, trains, aircraft, boats	nitrogen oxides, hydrocarbon gases, elemental carbon, primary particulate, sulfur oxides
Residential sources	gas water heaters, oil burners	nitrogen oxides, elemental carbon (soot), hydrocarbons, primary particulates
Agricultural and forestry sources	soil preparation, field burning, prescribed burning	soil dust, nitrogen oxides, elemental carbon, hydrocarbons, sulfur oxides, primary particulates

3.4 Definitions and Indices of Visibility Impairment

To quantitatively estimate benefits associated with increments in visibility, a measure or measures of visibility are needed. Also, monitoring technology must rely on objective measures of visibility. Since only humanly perceptible increments are defined as impairment, the relationship of visibility measures to human perception must be known. If mathematical simulations are used to relate emissions to physical measures, the dependence of visibility indices on mathematically predictable parameters must be established.

In this section commonly used visibility indices will be defined and discussed. What is known of their connections to human perception and physically measureable quantities will be outlined. No one visibility measure is appropriate for all times and locations. Hard and fast criteria for levels of perceptible changes are not at hand and may never be. The best that can be done at present is to present an array of measures to select from on the basis of sound technical advice.

Definitions of Visibility Indices

In the past there has been much confusion because of imprecise use of visibility-related terms. In this section we will define the most commonly used indices. It is first of all very important to distinguish three types of visibility-related indices--those directly related to human perception, those which are calculated from measures of light intensities, and those which are measures of optical properties of the atmosphere and airborne particles. Table 3.2 gives the commonly used, measured or calculated indices separated by this criterion.

Table 3.2: Commonly Used Indices of Visibility

Category	Examples	Reference
Measures of human perception	airport visual range	Meteorological Handbook No. 1, (U.S. Dept. of Commerce, 1975)
	Visual Air Quality Index	Craik (1979), Latimer et al. (1980), Malm et al. (1980a)
Measures of light intensities	contrast, blue-red luminance ratios, color contrasts, C.I.E. chromaticities, C.I.E. combined color and brightness scales, ΔE	EPA (1978), EPA (1979), Malm (1979)
Measures of optical properties of air and airborne particles	particle light-scattering coefficient, particle light-absorption coefficient, total light-extinction coefficient, standard visual range	Middleton (1954), U.S. EPA (1979)

Direct Measures of Human Perception

Currently only two indices unambiguously related to the human observer have been routinely measured. At some airports observers hourly estimate the maximum distance to which they can see in eight directional sectors. The prevailing visibility is determined from these observations and is the greatest distance to which large objects can be seen, which is equalled or exceeded over half of the horizon, not necessarily uninterrupted. This is also called airport visual range. It is important to distinguish this human observer determined visual range from standard meteorological range and standard visual range, defined below.

The usual definition of meteorological range is the distance at which the contrast of a black object to the ideal horizon is 2%. Since standard visual range is a somewhat artificial construction, it need not indicate the greatest distance at which real objects may actually be seen. Common experience has shown that this definition of visual range overstates the distance to which natural objects can be seen. This is because natural objects at a great distance are usually small, and small objects need a contrast greater than 0.02 to be seen. Also natural objects are never black. As a rule-of-thumb, one may expect to be able to observe natural objects out to about 75% of the meteorological range. (Snow-covered mountains are visible for longer distances because of their larger contrast.) If, in the study area, the geometric mean standard visual range is about 200 km, then targets up to 150 km should be typically observed. Meteorological range is theoretically related to the extinction coefficient of the atmosphere, a subject covered later.

The U.S. EPA and NPS have defined a further variant of meteorological range, the standard visual range, which takes into account the dependence of visual range on altitude. Visual range increases with the altitude of the observer because the air through which light passes becomes less dense. As some Class I areas are at high altitudes and some at sea level, the meteorological ranges cannot be directly compared. The standard visual range overcomes this problem by normalizing the meteorological range to an altitude of about 2,000 m. A precise definition is found in U.S. EPA (1980a).

A number of investigators have used airport prevailing visibility to determine long-term trends and geographical distribution of visibility (Trijonis 1979, Latimer et al. 1978). Trijonis has used airport visibilities in the Southwest to assign sources to visibility impairment.

The second direct measure of human perception of visibility, a Visual Air Quality Index (VAQI), is a simple subjective rating of the visual air quality on a scale, usually of 1 to 10. The Denver study (Mumpower 1980) elicited such subjective responses directly. The recent NPS/EPA studies of Malm et al. (1980a, b) had observers determine VAQI's from slides of scenic vistas. Similarly, an American Petroleum Institute study of Latimer et al. (1980) used VAQI's from slides.

The major problem with both humanly observed visual range and VAQI's are the subjective, unreproducible nature of the measurement. Malm et al. (1980a) found that for a midrange slide of VAQI about 5, 98% of the respondents assigned a value to it in the range of 2-8--a rather large spread. This means that for the same scene subjective ratings of 2 to 8 on a scale of 10 can be expected from different observers. Airport visual range is similarly hampered by subjective determinations as well as difficulty in finding suitable targets.

More serious, since visibility is a subjective phenomenon, is the difficulty in relating VAQI's and airport visual range to objective physical parameters. The studies of Malm et al. (1980a, b) and Latimer et al. (1980) attempt to answer these questions, but with equivocal success. For this reason it is difficult to relate results of mathematical models to either of these measures. However, Malm et al. (1980a) concluded that VAQI's of isolated scenic elements decreased exponentially with the product of extinction coefficient and distance to the scenic element. Furthermore, it was argued that the perception of a scene containing many scenic elements is equal to the combined perceptions of isolated scenic elements weighted in accordance with the fraction of the total area subtended by each specific scenic component. This study further concluded that the sensitivity of a scene to increases in air pollution was not affected by variation in the kind or amount of foreground features, nor was the sensitivity affected by cloud cover.

Finally, it is very difficult to establish thresholds for these measures since controlled experiments are almost impossible to conduct. Using slides Malm et al. (1980a) have made an attempt at determining a human perception threshold. However, this work is of a research nature and needs further study and review.

While the idea of VAQI does not lend itself to the determination of a threshold, a guess as to a reasonable threshold for visual range would be ±.05 km as a perceptible change for an object near its limit of detection. This is not a percentage change, i.e., for an object of contrast -0.15 a noticeable degradation might be to a contrast of -0.10. This is based on experience with a large number of slides of scenic vistas in the Southwest with associated objective measurement of target contrast.

Measures of Light Intensity

In an attempt to bridge the gap between human perception and the world of physically reproducible measures, much attention has been focused on measurements of light and various measures calculated from these observations. Also, several recent visibility models (U.S. EPA 1980c, Drivas et al. 1980, Williams et al. 1979) predict light intensities for several wavelengths (colors) of light. Thus, these visibility indices based on light measurements offer the hope of connecting models with human perception of visibility degradation. The vital link between light and perception is the realm of visual psychophysics and its application to the natural environment is not simple.

In this work, "brightness" will refer to the humanly perceived sensation of lightness and darkness and "color" to the humanly perceived sensation of color. However, these human perceptions cannot be measured by instruments. The physical antecedents of brightness and color, which can be objectively measured, are the amount of light energy entering the eye and its distribution among visible wavelengths. The multiwave-length telephotometer or, more accurately, teleradiometer, is the commonly used instrument which measures the light energy, or radiance, coming from a distant area in several narrow wavelength bands. Physical contrast (or simply contrast) is determined by the ratio:

$$C(\lambda) = \frac{L_o(\lambda) - L_B(\lambda)}{L_B(\lambda)} \qquad (3\text{-}1)$$

where:

$C(\lambda)$ = contrast of the object to background at wavelength λ;

$L_o(\lambda)$ = light intensity of the object at wavelength λ; and

$L_B(\lambda)$ = light intensity of the background (usually sky) at wavelength λ.

The relationship between perceived contrast (relative lightness and darkness) and the measured physical contrast has never been directly studied in the natural environment. Extensive laboratory studies (Cornsweet 1970) have shown that the relationship is not simple but is a complex function of ambient lighting and spatial interactions between the object (or its texture) and its background.

The dependence of contrast on wavelength is important, and usually green light of wavelength 550 nanometers (nm) is specified in the definition. Contrasts of grey objects are between 0 and -1 and are often quoted as a percentage, e.g., -10%, -20% contrast. Bright objects, such as snow-covered mountains or bright rocks can be brighter than the sky, they have contrasts that are positive and can range as high as +4 or +5.

Blue-red ratios are simply defined as the ratio of blue light intensity to red light intensity. The wavelengths most often used are 450 nm for blue and 650 nm for red. In most applications the blue-red ratio is normalized to the blue-red ratio of the horizon, i.e., the blue-red ratio of the horizon is defined to be 1.0.

Chromaticities and combined brightness and color difference formulas, ΔE, are functions of light intensities over several wavelengths which have been related to color perception under controlled laboratory-like conditions. The definitions are highly technical and can be found in texts such as Wysyecki and Stiles (1970), or for a brief account, see Latimer et al. (1979) or the EPA Report to Congress.

The previously quoted studies of Malm et al. (1980b) and Latimer et al. (1980) have made considerable effort to relate these measures to human perception of visibility as judged by VAQI estimates from slides. No clear-cut thresholds emerge from these efforts, however. In general, absolute thresholds of 0.02 for contrast, -0.1 for blue-red ratio and ±4 for ΔE are acceptable but perhaps conservative estimates. Since ΔE is calculated from chromaticities, no separate thresholds for chromaticities are needed.

Measures of Optical Properties of the Air and Airborne Particles

Other measures of visibility that are often mentioned are light-scattering coefficient, light-extinction coefficient, and light-absorption coefficient (Middleton 1954). These concepts are twice removed from the human perception of visibility, since they do not describe either human sensations or light itself. They are properties of the atmosphere and describe how light interacts with the gases and particles in the atmosphere. Light passing through the atmosphere is either absorbed, scattered, or transmitted unchanged. The extinction coefficient is the fraction of incident light which is not transmitted by a small unit length of the atmosphere, i.e., an extinction coefficient of 0.04 km^{-1} means that over a 1 km path length, roughly 4% of the incident light would be absorbed or scattered by gases and particles and 96% would be transmitted.

It is interesting to note that for an important special case, contrast is reduced by the same law as light intensity; i.e., in the example above, the contrast of an object would be reduced about 4% in each kilometer of distance. This is the case of horizontal views of objects against the horizon. The atmosphere must be homogeneous and the curvature of the earth is ignored. This last constraint is not well satisfied for views over 75 km. Also, many objects are not seen against the true horizon, but against a higher portion of the sky or other objects. Still, this law of contrast change, known as Middleton's Law (Middleton 1952), is a very useful tool. Middleton's law can be used to derive a relationship between standard visual range and the extinction coefficient of the atmosphere; this is called Koshmieder's Law, which states that the visual range is 3.9 divided by the extinction coeffienct.

The total extinction coefficient of the atmosphere has four components: scattering and absorption by both gases and particles. Each wavelength of light is scatteredd and absorbed in differing amounts. In the following paragraphs, each of these components is discussed.

Pure scattering of light by colorless gases (such as oxygen and nitrogen, 99% of the atmosphere) is known as Rayleigh scattering; it is about four times larger for blue light than red light. For this reason the sky overhead is perceived as blue; pure white sunlight is composed of all colors of light, and the blue portion of the spectrum is efficiently scattered by the atmospheric gases, giving a diffuse blue color to the visible sky, while the red and yellow light is, for the most part, transmitted completely through the atmosphere, giving sunlight a warm golden color. At sunset, when the sunlight must travel through a greater atmospheric depth because the sun is on the horizon, the sky acquires a reddish tint due to decreased transmittal of yellow and green and increased scattering of red light. Since Rayleigh scattering depends on the number of molecules in the air, it also varies with ambient temperature and pressure. For green light (wavelength of 550 nm) about 2,000 m above sea level, it is 0.01 km^{-1}.

The only ambient gas able to absorb visible light is nitrogen dioxide. It affects blue light to a much greater extent than other wavelengths. In high concentrations, it will make white light look red-brown. In plumes of modern power plants, nitrogen dioxide can be the dominant cause of visibility impairment.

Particle light-scattering is usually the major physical cause of visibility degradation by pollution. Small particles, in the size range of bacteria (0.1 to 1.0 μm diameter) are by far the most efficient in scattering light and reducing visibility on a per unit mass basis. Unfortunately, these particles are in the size range that keeps them suspended in the atmosphere for most of the time. Pollution aerosols can also cause discoloration by preferential backscattering of red light (Husar and White 1976).

Particle light-absorption is typically only 5 to 10% of total extinction unless significant amounts of elemental carbon are present in the suspended particles. In some urban areas, e.g., Denver, the particle absorption coefficient can, at times, equal or exceed the scattering coefficient (Heisler et al. 1979). Because absorption reduces the total amount of light energy transmitted through the atmosphere, it produces a grey haze which is often particularly offensive to observers. As pointed out in Henry (1979a), a low, grey haze layer seen next to a deep blue sky (a situation which often occurs in the West) may take on the complementary color, a yellow-brown. This color is produced by the overcompensation of the eye to the blue sky.

3.5 Visibility Monitoring and Natural Conditions Affecting Visibility

To those assessing visibility impairment and the benefits of improved visibility, monitoring existing visibility and understanding the natural conditions which can affect visibility are critical. This is emphasized in the visibility regulations. The determination of significant impairment must take "into account the geographic extent, intensity, duration, frequency and time of the visibility impairment, and how these factors correlate with (1) times of visitor use of the mandatory Class I Federal area, and (2) the frequency and timing of natural conditions that reduce visibility." (Federal Register, Vol. 45, No. 233, p. 80091). Currently, monitoring is the only reliable source of information concerning frequency of occurrence, duration and geographical extent of visibility impairment and natural variability of visibility.

There are many examples of the importance of these concepts. Improved visibility at night or during off-season periods is of limited benefit. In some areas, natural fog or haze may limit the noticeable impairment of visibility. Also, long-term monitoring in pristine areas is the only obvious way to directly determine baseline natural conditions and the range of natural variation in visibility.

In this section, a brief overview of visibility monitoring technology and programs are presented followed by a brief discussion of natural impediments to visibility.

Visibility Monitoring Technology

The output of a monitoring program of greatest utility to those engaged in benefit analysis are the tables and graphs showing the frequency of occurrence and behavior of visibility-related parameters. The methods and associated parameters, advantages, limitations and uses are summarized in Table 3.3, which is taken from Protecting Visibility: An EPA Report to Congress (EPA, 1979). Detailed recommendations for a visibility monitoring program can be found in the EPA's Interim Guidance For Visibility Monitoring (EPA 1980a).

Most of the methods and parameters have been discussed in Section 3.4. However, some discussion of the importance and use of the airborne particulate measurements is appropriate. The Guidelines for Visibility Monitoring recommends separate collection of coarse, greater than 2 μm, and fine, less than 2 μm, diameter particles and some analysis of their chemical composition. This is because airborne particles typically exist in at least two mass modes, which tend to have fairly distinct sources and effects on visibility.

The fine particle mode (<1 or 2 μm) consists chiefly of primary combustion particulates or particles formed from combustion generated gases and other man-made sources. Sulfates, organic matter and nitrates are important contributors to fine particle mass. Elemental carbon (soot) and industrial process emissions are often in this size range. Since these particles efficiently scatter or absorb light, they are a very important and are often the dominant source of visibility impairment.

The coarse particles, greater than 1 or 2 μm diameter, are principally derived from soil dust. In rural areas this can be natural windblown dust or dust raised by vehicles or farm equipment. Unless a dust storm situation exists, the particles in this mode are seldom responsible for more than 10% of the particle light-extinction coefficient.

TABLE 3.3: VISIBILITY MONITORING METHODS[a]

Method	Parameters Measured	Advantages	Limitations	Preferred Use
Human observer	Perceived visual quality Atmospheric Color Plume blight Visual range	Flexibility, judgment; large existing data base (airport visual range).	Labor intensive; variability in observer perception; suitable targets for visual range not generally available.	Complement to instrumental observations; areas with frequent plume blight, discoloration; visual ranges available target distances.
Integrating nephelometer	Scattering Coefficient (b_{scat}) at site relatable to fine aerosol	Continuous readings; unaffected by clouds, night; b_{scat} directly neglects extinction from night; b_{scat} directly relatable to fine aerosol concentration at a point; semi-portable; used in a number of previous studies; sensitive models available; automated.	Point measurement, requires assumption of homogeneous distribution of particles; distribution of particles; neglects extinction from absorption, coarse particles >3 to 10 µm; must consider humidity effects at high RH.	Areas experiencing periodic well mixed general haze; medium general haze; medium to short viewing distances; small absorption coefficient (babs); relating to point composition measurements.
Multiwavelength teleradiometer	Sky and/or target radiance, contrast at various wavelengths	Measurement over long view path (up to 100 km) with suitable illumination and target, contrast transmittance, total extinction, and chromaticity over sight path can be determined; includes scattering and absorption from all sources; can detect plume blight; automated.	Sensitive to illumination conditions; useful only in daylight; relationship to extinction, aerosol relationship possible only under cloudless skys; requires large, uniform targets.	Areas experiencing mixed or inhomogeneous haze, significant fugitive dust; medium to long viewing distances (1/4 of visual range); areas with frequent discoloration; horizontal sight path.
Transmissometer	Long path extinction coefficient (b_{ext})	Measurement over medium view path (10-25 km); measures total extinction, scattering and absorption; unaffected by clouds, night.	Calibration problems; single wavelength; equivalent to point measurement in areas with long view paths (50-100 km); limited applications to date still under development.	Areas experiencing periodic mixed general haze, medium to short viewing distance areas with significant absorption (babs).

TABLE 3.3: VISIBILITY MONITORING METHODS[a] (Continued)

Method	Parameters Measured	Advantages	Limitations	Preferred Use
Photography	Visual quality Plume blight Color Contrast (limited)	Related to perception of visual quality; documentation of vista conditions.	Sensitive to lighting conditions; degradation in storage; contrast measurement from film subject to significant errors.	Complement to human observation, instrumental methods; areas with frequent plume blight, discoloration.
Particle samplers	Particles	Permit evaluation of causes of impairment.	Not always relatable to visual air quality; point measurement.	Complement to visibility measurements.
Hi-Vol (High Volume Air Sampler)	TSP (Total Suspended Particulates)	Large data base, amenable to chemical analysis; coarse particle analysis.	Does not separate sizes; sampling artifacts for nitrate, sulfate; not automated.	Not useful for visibility sites.
Cascade impactor	Size segregated particles (>2 stages).	Detailed chemical, size evaluation.	Particle bounce, wall losses; labor intensive.	Detailed studies of scattering by particles <2 μm.
Dichotomous and fine particle samplers (several fundamentally different types)	Fine particles (<2.5 μm) coarse particles (2.5 to 15 μm) inhalable particles (0 to 15 μm)	Size cut enhances resolution, optically important aerosol analysis, low artifact potential, particle bounce; amenable to automated compositional analysis; automated versions available; large networks under development.	Some large-particle penetration; 24-hour or longer sample required in clean areas for mass measurement; automated version relatively untested in remote locations.	Complement to visibility measurement, source assessment for general haze, ground level plumes.

[a] From Protecting Visibility, An EPA Report to Congress, p. 3-5 (U.S. EPA 1979).

Visibility Monitoring Programs

Historically, visibility monitoring has centered on airport visual range. For the past ten years visibility monitoring as part of air quality studies has been a case of running a nephelometer in an urban area. Only recently has monitoring directed at air quality and visibility in pristine areas begun. In the next section some of the results of the pioneering Cedar Mountain study in central Utah are discussed. This study was begun in 1976 by the National Oceanic and Atmospheric Adminstration (NOAA) and the EPA. An extensive network of visibility monitoring sites has grown as part of the VIEW (Visibility Investigative Experiement in the West) which is a joint endeavor of the National Park Service (NPS) and EPA. Some visibility data from this network begins in September of 1978. The periodic reports, e.g., Walther and Newburn (1980), summarizing the teleradiometer measurements of contrast and calculated visual range are a unique source of information on frequency of occurrence, time, extent and intensity of variations in visibility in the VIEW study area, shown in Figure 3.2. Figures 3.3 and 3.4 are examples of the available information from the VIEW program. In the next section natural variability in visibility and its causes are discussed.

Visibility and Natural Conditions

Field studies have indicated the importance of large scale meteorology patterns in determining visibility and natural variation in visibility. Besides determining the direction of transport of pollutants and their dilution, meteorology determines large-scale temperature, pressure and humidity patterns. Data from the Cedar Mountain Study, in central Utah, (DeNevers et al. 1979) have shown that variations in visibility are to a large extent determined by these large-scale variables. Similarly, widespread low visibilities in the eastern United States are often accompanied by warm moist air which originates in tropical seas (Husar et al. 1979).

Variations in synoptic meteorology represent the large driving force behind natural variation in visibility. Latimer et al. (1978) uses airport visibility data to estimate long-term trends in visibility and geographical distribution of average airport visual range. The map of existing visual range, Figure 3.5, shows that, in general, the West has the best visual range. One must remember that this use of airport visibility data is quite different from that for which it was designed and obtained. There are many ambiquities and pitfalls to beware of interpreting this data. But it does offer the only long-term record available of a visibility-related parameter.

Some natural sources produce primary visibility-reducing particulates and gases which convert to secondary particulates. Table 3.4 lists some natural sources of reduced visibility. Soil dust consists mostly of particles greater than 1 μm and larger which are outside the most efficient light-scattering size range. In sufficient quantity, as in a dust storm, these particles can cause significant visibility degradation. Quasi-natural dust from roads or agricultural activities can be noticeable, but since these particles settle out rapidly, their effect is usually local.

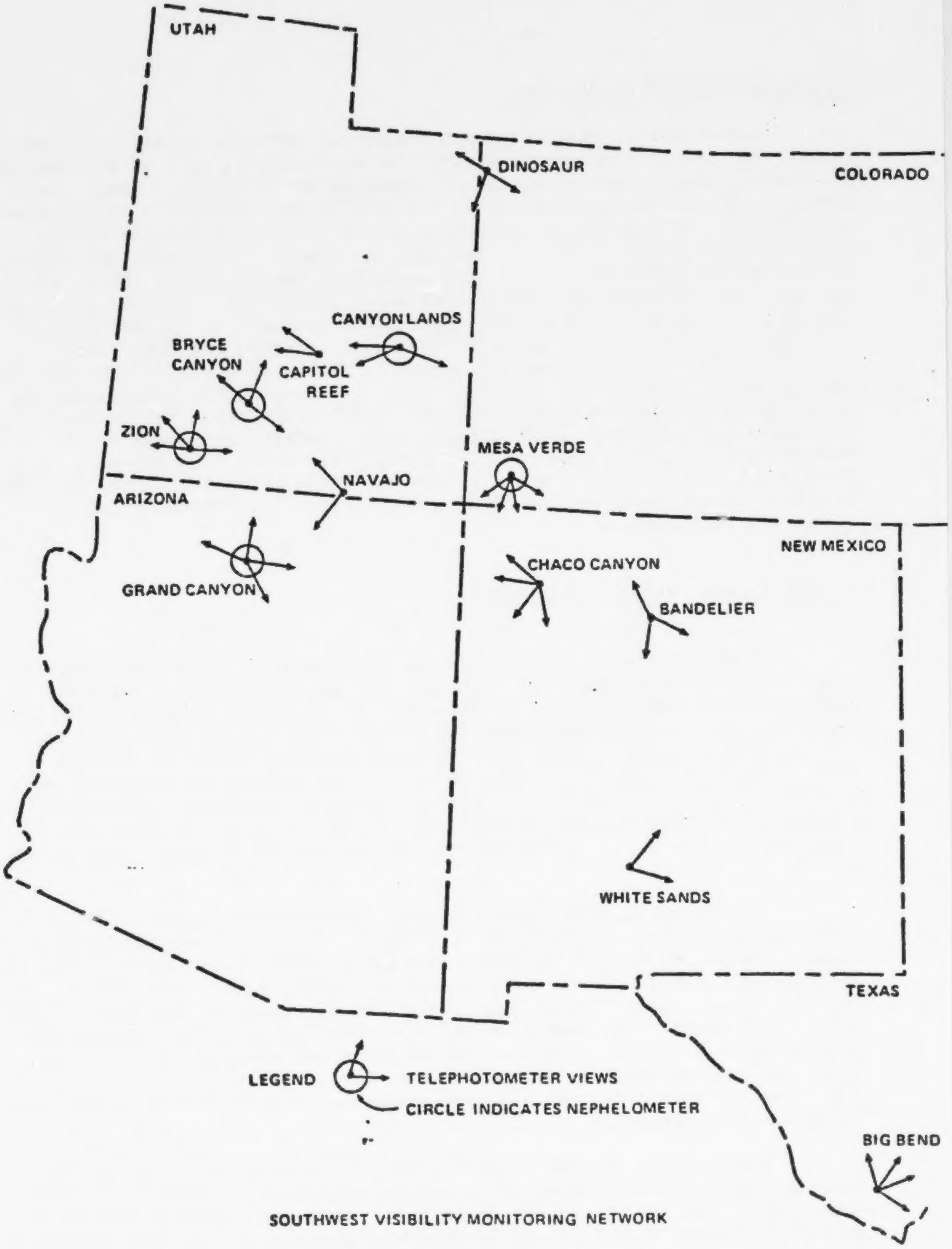
UTAH
DINOSAUR
COLORADO
CANYON LANDS
BRYCE CANYON
CAPITOL REEF
ZION
MESA VERDE
NAVAJO
ARIZONA
NEW MEXICO
GRAND CANYON
CHACO CANYON
BANDELIER
WHITE SANDS
TEXAS
LEGEND
TELEPHOTOMETER VIEWS
CIRCLE INDICATES NEPHELOMETER
BIG BEND
SOUTHWEST VISIBILITY MONITORING NETWORK

Figure 3-2. Project VIEW - EPA/NPS Southwest Visibility Monitoring Network.

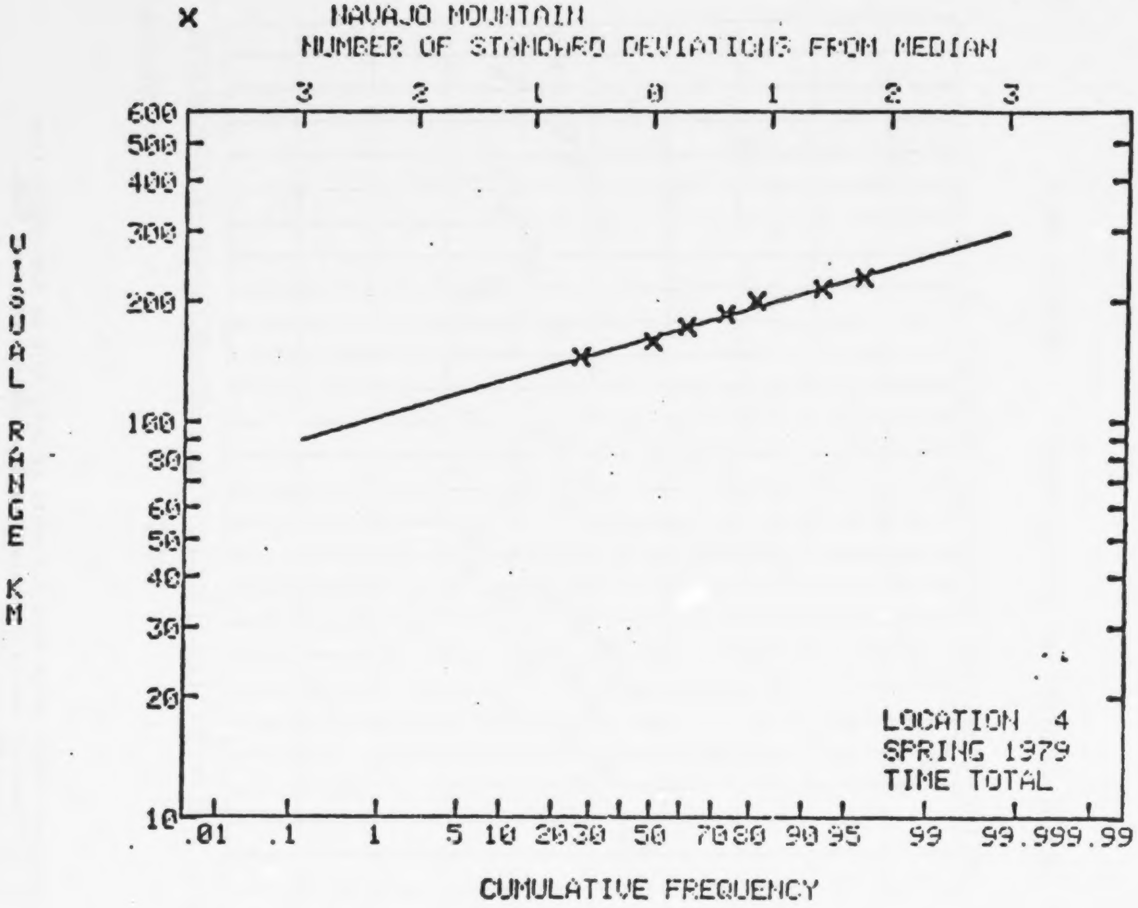

Figure 3-3. Cumulative Frequency of Occurrence for Standard Visual Range derived from teleradiometer observations of Navajo Mountain 140 km distant from Bryce Canyon National Park. (Walther and Newburn 1980)

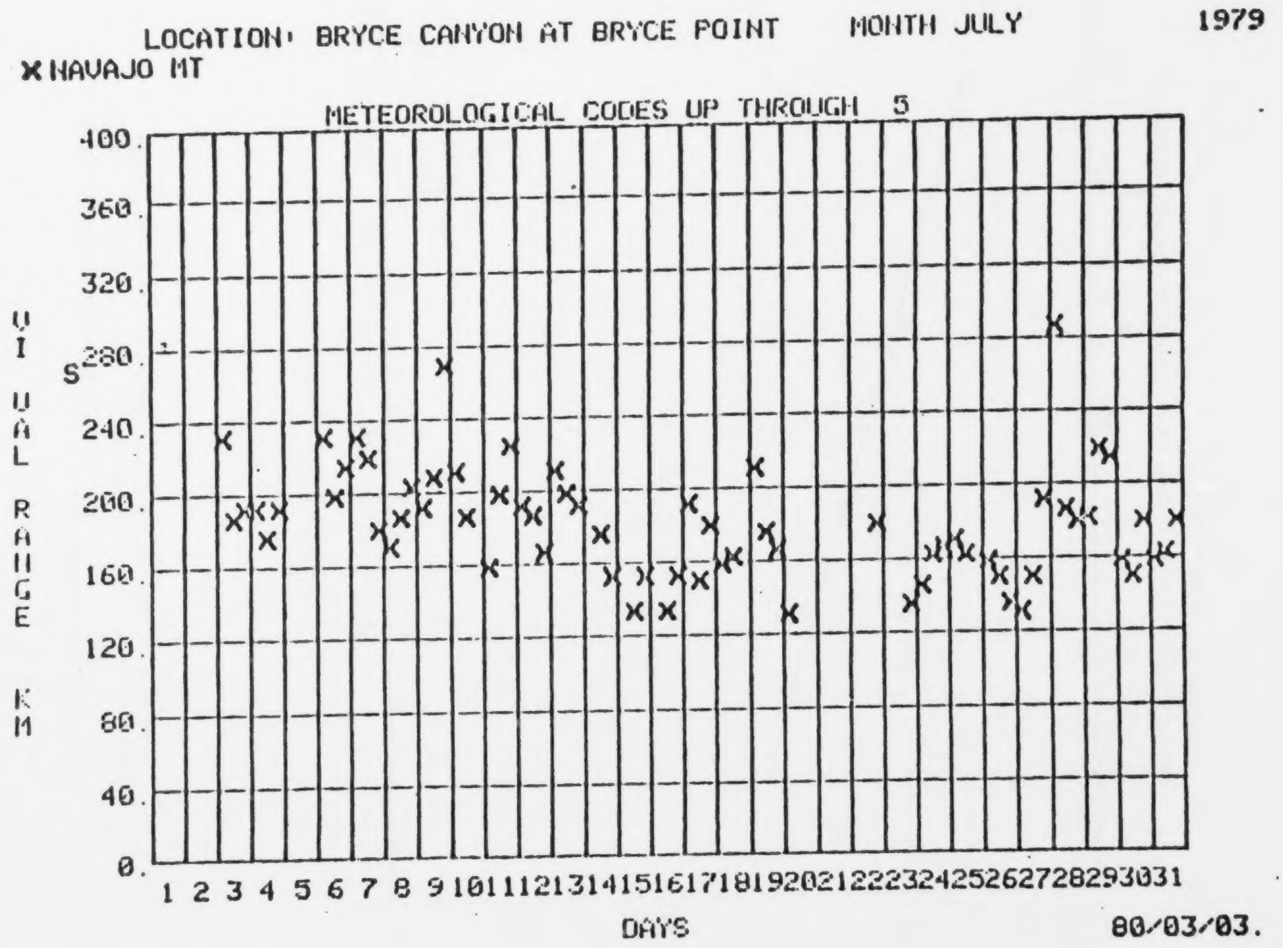

Figure 3-4. Standard visual range data for month of July 1979 as determined from observations of Navajo Mountain from Bryce Canyon National Park. (Walther and Newburn 1980)

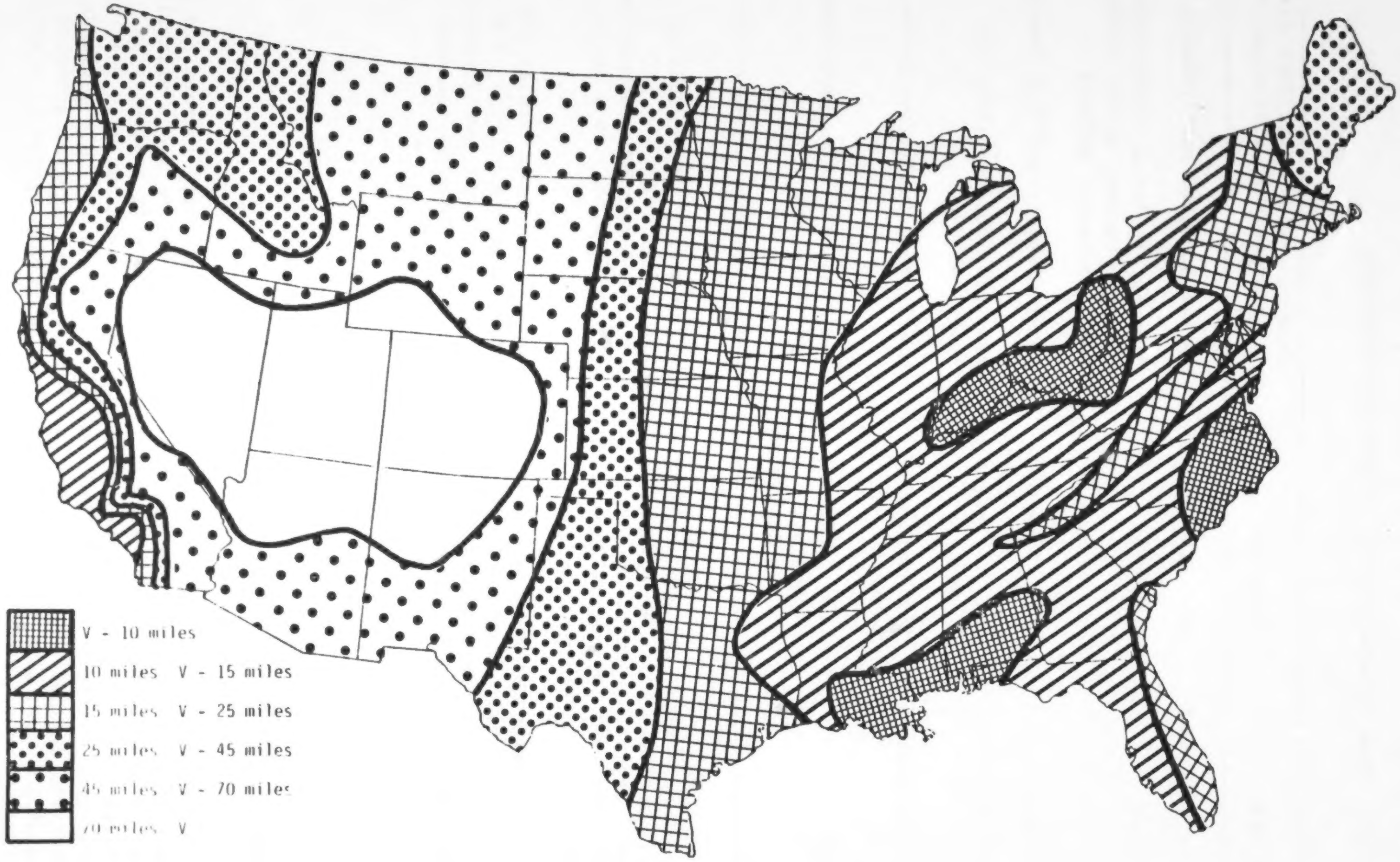
V - 10 miles
10 miles V - 15 miles
15 miles V - 25 miles
25 miles V - 45 miles
45 miles V - 70 miles
70 miles V

Figure 3.5. Map of Existing Visual Range (from EPA Report to Congress, page 4)

Table 3.4: Some Natural Sources of Reduced Visibility

Source Type	Examples	Products which contribute directly or indirectly to visibility reduction
Airborne soil dust	dust storms	coarse and fine particulates
Wood fires	wildfire	fine particulates, hydrocarbons nitrogen oxides, sulfur oxides, soot (elemental carbon)
Water hazes	fog, rain, etc.	water droplets and high humidity
Volcanic activity	Mt. St. Helens, Kilewa	fine particulates (ash) and sulfur oxides
Geothermal areas	Yellowstone, Geysers, CA	water vapor, sulfurous gases
Biogenic	Blue Ridge Mountains, Smokey Mountains	terpines, ethylene, isoprenes, hydrocarbons

Wood fires can produce very significant visibility reductions even at large distances. These fires produce many particles in the 1 to 0.1 μm range. Some of these particles contain soot from incomplete combustion. Gases given off include nitrogen oxides, hydrocarbons and, to a lesser extent, sulfur oxides.

Water hazes and fog are important natural causes of visibility reduction. Water droplets themselves interfere with visibility. Also, high humidity conditions will encourage the growth of very small particles below the light scattering region into a size range which is the most efficient in scattering light.

3.6 Presentation of the Visual Environment

Review of Recent Applications

After reading the previous Section 3.4 visibility indices one may wonder if a non-technical person can ever make decisions about visibility based on numerical measures alone. In terms of benefit analysis, an increase of ΔE of 4.6, for example, may be perceptible but what does it really mean in terms of the appearance of the vista? To help decision makers and designers of visibility benefit analyses, several attempts have been made to use pictorial graphic displays of scenic vistas in visibility studies.

The first and most advanced attempt was that at Los Alamos Scientific Laboratory (LASL). Williams et al. (1979) report how they used a sophisticated computer generated display to simulate the appearances of power plant plumes. Malm et al. (1980b) has used a similar technique to study the thresholds of perception of layered haze. Of course, the previously much cited studies of Malm et al. (1980a) and Latimer et al. (1980) are based on photographic slides with coincident physical quantities.

Similar "calibrated" photographic slides have been used to demonstrate potential visual air quality degradation in the Kaiparowits Plateau of southern Utah for various coal production scenarios on Bureau of Land Management lands (BLM 1980).

Given all this activity and potentially very useful applications to benefit analysis, a closer look at display techniques for visibility studies is reasonable. Because of the great influence a photograph can have on a non-technical person, it is only fair that in the review below a very critical approach is taken.

General Principles

The basic goal of a graphic display for visibility work is to reproduce as accurately as possible the original perceived view. Unfortunately, this is an extremely complex problem. The major source of the trouble lies in the extreme ability of the eye to adapt to its surrounding conditions. Usually the reproduction is to be viewed under different lighting conditions at different ambient luminance levels from the original, and often the reproduction will be smaller or larger than the original scene. These factors have to be taken into account in producing the reproduction. Chapter 19 of The Theory of the Photographic Process (James 1977) describes in detail the psychophysical engineering that goes into designing films which will produce pleasing pictures.

This brings up another issue. Henry (1979b) reviews several excellent studies which show that the most preferred colors of skin, grass and sky in photographs are quite different from the actual, natural colors. The memory colors, i.e., colors of sky, etc., picked from memory are different from the "real" colors and the preferred colors. This phenomenon is widespread and well documented.

The result is that a reproduction with exactly the same relative intensities of all colors (wavelengths) as the original scene will not look like the original scene and will probably be judged less pleasing than the real scene. The work of the LASL group and Malm et al. (1980b) do not appear to account fully for these facts.

On the other hand, if ordinary color film is used to make slides, as in Malm et al. (1980a) and Latimer et al. (1980), then, since these films have been designed to produce pleasing pictures, the reproductions will look better than the original scene. In fact, Malm et al. (1980a) does report this to be so. Further study of the use of photographs in this manner is obviously called for.

Other Specific Problems

Loss of fine contrast detail by most reproduction is inevitable. Since perception of fine detail is probably an important perceptual clue a loss of detail will distort the reproduction. This is especially true of video based techniques, such as with the LASL simulated photo technique.

Use of telephoto lenses tends to distort the size and perspective of the view. Yet, most studies using slides have used telephoto lenses on the camera. Processing and exposure are very important in producing accurate photographs. Control photos of standard grey scales and other color patches, such as those used in darkrooms, are recommended.

Other Alternative Approaches

Regular Photography.

Experience from Malm et al. (1979) has shown that regular photography twice a day of long-distance vistas using a single-lens reflex camera with a 135 mm lens and Kodachrome 25 film will produce during one year a good selection of slides showing various levels of air quality, cloudiness and hazes under two different illumination conditions.

Kodachrome 25 seems to produce an acceptable color and its standardized processing by Kodak, Inc. is very repeatable. Although, as recommended above, pictures of standard scales should be taken for quality control checks. Taking the pictures around 9 am and 3 pm local time provides illumination from almost opposite directions. The 135 mm lens, combined with a 135 mm lens in the slide projector and placing a person near the projector while viewing a screen at a normal distance (20 feet), makes a good image size and field of view.

Regular photography can capture hazes of varying intensity at almost any location because of the large extent of regional hazes (many hundreds of kilometers). Distinct plumes from power plants, smelters, controlled forest burns and other sources may be photographed at relatively close locations (up to few tens of kilometers). Sample regular photography slides for one visibility benefits study may be found at the back of the guidebook.

In addition to the more proven technique of regular photography, there are a number of other approaches which could be useful to a benefit analysis. It should be noted that these are only suggestions and that most of the techniques are untried.

Picture Modifications for Hypothetical Plumes. One approach to representing visibility levels is through modification of existing pictures or construction of simple artists renderings. These may range from very simplistic attempts which merely retouch existing pictures to rather elaborate systems such as the simulated photograph technique (see Malm et al. 1980b).

Overlay Technique. One simple method involves overlaying layers of translucent material over portions of the original picture. In this case a key difficulty is the proper choice of the material to be overlayed and the difficulty with proper gradations in material in order to represent gradations in plume material or distances to terrain features. The color effects and gradation caused by sun angle effects are also difficult to represent in this fashion.

Retouch Technique. The method of retouching pictures is similarly difficult. Furthermore, it is probably even more difficult to assure that the retouching is a technically defensible representation of appropriate visibility impairment levels.

Real Smoke Plumes. Another possibility is the use of infrequent real smoke plumes to represent possible future smoke plumes. The difficulty of this approach is that it may be very difficult to find existing plumes with characteristics appropriate to a hypothetical source.

Artist's Rendering Technique. This approach involves computing the sky color in terms of Munsell color chips and employing a commercial artist to paint the scene with calculated sky colors.

Plume Superposition Technique. Another technique involves using imaging technique to place an actual plume, photographed for a similar source in another region during similar lighting and atmospheric conditions on to an actual scene. This technique can not be used if there is a mixed background of sky and terrain features. Furthermore, in the superposition approach care must be taken to control the large number of parameters which may influence the perception of the scene.

3.7 Visibility Modeling

A valuable means of relating source emissions to visibility impacts are by mathematical simulation, modeling, and evaluation of monitoring data. Each of the components of the visibility problem, as shown in Figure 3.1, can be reduced to mathematical relationships and programmed into a computer. Such models must pass two criteria to be really useful: 1) they must be scientifically sound, i.e., they must be based on valid assumptions and simplifications, and 2) they must be able to accurately predict observed visibility degradation in the real world. The distinction here is important, since a sound, valid model may give inaccurate results because of poor input information. On the other hand, a grossly oversimplified, unsound, and invalid model may produce reasonable predictions by the well known process of cancellation of errors.

Visibility models currently available concentrate on single source, near source (less than 50 km) impacts on visibility. This is in line with the phased approach of the EPA, of which Phase I focuses on control of existing single sources strongly implicated in causing visibility degradation in protected Class I areas. The EPA has issued a User's Manual for the single source model PLUVUE (U.S. EPA 1980c). The associated guideline Workbook on Estimating Visibility Impairment (U.S. EPA 1980b) gives the derivation and procedures for two less sophisticated levels of modeling, to be used as screening tools to quickly sort out those sources which can potentially, under worst case conditions, impair visibility in a protected Class I area. Other models described so far in the literature are for the most part similar to the PLUVUE model in basic assumptions and approach to the optical calculations and in choice of calculated visibility indices.

The PLUVUE model has received limited validation as part of the EPA's VISTTA (Visibility Impairment due to Sulfur Transformation and Transport in the Atmosphere) program. Blumenthal et al. (1980) presents an overall summary of the project, and Bergstrom et al. (1980) reports the initial model validation studies. Further work is needed in this area. Several organizations other than the EPA are expected to attempt field validation of visibility models.

In the benefit analysis, simulations of visibility indices should be used with care and, if possible, checked against real world experience. This is especially true if calculations of frequency of occurrence of the indices are also made. One fruitful approach is to combine model simulations with historical photographs from the VIEW program network. This approach has been used with some success for estimating visual impact of coal development in southern Utah (BLM 1980).

3.8 The Effect of Definition, Measurement, and Presentation of Air Quality Conditions Upon Benefit Measures

Before economic techniques can be applied to obtain monetary measures of value for changes in air quality, great care must be taken to define, measure, and present the alternative air quality levels. Unmeasured changes, or lack of control in many of the experimental factors, will influence and bias the valuation process. These factors include the choice of method, location and timing for measuring air quality; the type of pollutants or impacts to be measured; and when used, pictorial presentation factors, including the choice of lens types (135mm versus 50mm), the amount of clouds or snow cover in scene, whether the scene is mountainous or flat terrain, and the like. This section discusses the impact upon benefit meausrement of variation in these factors.

Two problems should be considered when comparing alternative levels of visibility aesthetics. First, all influencing factors other than the air quality measure of interest should be held constant or accounted for in the analysis. Second, the most appropriate characteristics should be chosen for measuring and describing the attributes of alternative air quality levels that influence individuals' behavior at the affected site. These problems must be addressed, because if unmeasured influences affect an individual's utility this will be reflected in the monetary measures of benefits and will inadvertently create inaccuracies.

The need for accuracy and control is demonstrated in Figure 3.6, which demonstrates that as some measure of visibility aesthetics increases, the total utility of visibility aesthetics to an affected individual also increases. F1 and F2 represent two levels of a factor that might influence the valuation process, such as location, scenic content, or the type of pollutant measure used, etc. For discussion purposes assume F is the amount of cloud cover in pictorial representations of two alternative visibility levels A and B.

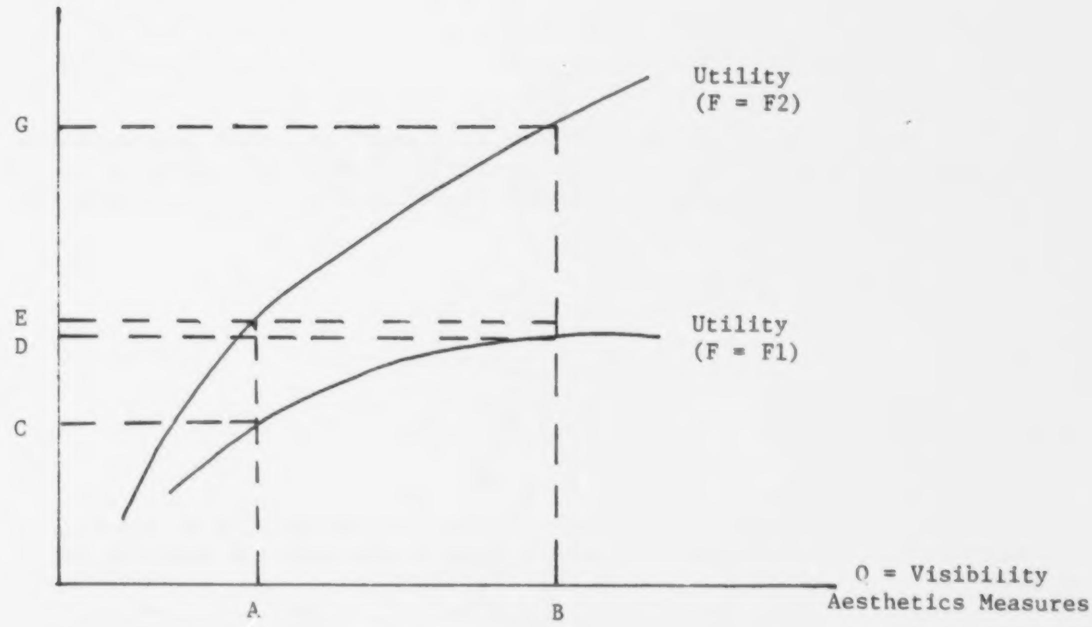

Figure 3.6

The Effect of Varying Definition and Presentations Upon Utility Valuation

(F represents influencing factors such as location, pollution measure, time of day, scene characteristics, etc., where F1, F2 represent alternative levels or sites.)

At cloud cover level F1, the change in utility as visibility aesthetics change from level A to level B is the distance CD. The first problem would occur if level A is presented to the individual with cloud cover F1, and level B is presented with cloud cover F2. Then the difference in utility would be measured as CG, which inadvertantly measures both changes in utility from visibility aesthetics (CD) and the changes in utility from cloud cover (DG). This problem can be avoided by controlling as many extraneous elements as possible and by statistically accounting for changes in uncontrollable factors.

The second problem of choosing the appropriate level of the influencing factors is more difficult. In Figure 2.8 the choice of F1 yields a change in utility of CD for changes from visibility levels A and B, while the choice of F2 yields the much larger change EG. This problem can be reconciled through the use of accepted standards, or by varying the levels of extraneous influences and testing for and measuring their influence. The choice of standards, which is not often clear-cut, is discussed earlier in this chapter.

Both problems may be treated concisely in the following mathematical model for an individual:

$$V = f(Q,\ F,) + E \qquad (1)$$

Where V, Q, F are as in Figure 2.10 and E are other unaccountable or random influences. Our concern is with $\partial V/\partial Q$ over the Q range of interest. If the F influence varies and is not accounted for, one measures

$$\left.\frac{\partial V}{\partial Q}\right|_{F=F1} + \left.\frac{\partial V}{\partial F}\right|_{Q=B}$$

where

$$\left.\frac{\partial V}{\partial Q}\right|_{F=F1}$$

is the partial derivative of U with respect to Q given F is at the F1 level, etc.). As long as this second term is non-zero the analysis is biased.

The second problem amounts to a case where $\left.\frac{\partial V}{\partial Q}\right|_{F=F1} \neq \left.\frac{\partial V}{\partial Q}\right|_{F=F2}$ Here it is probably most appropriate to choose a standard if applicable, such as scene content, pollutant measure, time of day for measurements, etc., or to determine $\partial V/\partial Q$ based upon the joint probability distribution of Q and F, P(Q, F). In the case where Q takes on two values, A and B, and F takes on N levels Fi, where $i = 1,2..N$, then $\Delta V/\Delta Q$ may approximate $\partial V/\partial Q$ as:

$$\frac{\Delta V}{\Delta Q} = \left[\sum_{i=1}^{N} P(F = Fi,\ Q = B) * f(B,Fi) - \sum_{i=1}^{N} P(F = Fi,\ Q = A) * f(A,Fi) \right] / (B-A) \qquad (2)$$

where for example, P(F = Fi,Q = B) represents the joint probability of F = Fi and Q = B.

Because f(Q,F) is often estimated in some variant of its difference form:

$$(3) \quad V = f(\Delta Q,\ \Delta F) + E$$

equation 2 would then need to be suitably modified. In most cases it would be appropriate to simply control as many influences as possible because P(F,Q) may be unknown.

CHAPTER 4

PRACTICAL APPROACHES TO MEASURING ECONOMIC BENEFITS ASSOCIATED WITH CHANGES IN VISIBILITY AESTHETICS

4.1 Actual Market Versus Contingent Market Approaches

This chapter discusses practical approaches that have been developed to measure the economic value of changes in visibility. Two sets of approaches--bidding methods and residential property value studies--are examined in detail because they are well established in theory and have been the predominant methods applied in air quality benefit analysis to date. The chapter discusses the theoretical basis of these methods, how they are applied, their strengths and weaknesses and when they may be relied upon for doing visibility benefit analysis. Because of the complexity of valuing a non-market public good, there is a great deal of underlying measurement error in both types of approaches. Many of the major strengths or weaknesses of an approach relate to the ability to minimize these measurement problems.

Special methods are necessary for valuing visibility, as with most environmental goods, because of its special status as a "public good": the use of visual aesthetics is non-exclusive and there are no existing markets from which prices and demand curves may be directly obtained. Given this absence of direct market data, the method used to assess the value of visual aesthetics must rely upon one of two general classes of valuation approaches: (1) methods that indirectly use actual market data regarding the relationship between private markets and public goods, combined with special analytic methods, to infer implicit prices and the demand for the public good; and (2) methods that establish values directly through the use of hypothetical, or what is known as "contingent market" situations posed to survey respondents.

The first group is labeled "actual market approaches" because these methods attempt to use existing market data in cases where the selection of a market good may vary with visibility levels, such as the choice of residential location. Property value studies, most of which use the hedonic price technique to estimate an implicit price for air quality, fall into this category. This type of approach presupposes that individuals respond in a predictable manner to environmental conditions that they encounter in places where they live, work, and recreate. For example, it is assumed the individuals prefer to live in neighborhoods where breathing the air is not damaging to their health and prefer to visit parks where the air is clear. This approach further assumes that the intensity of these preferences is revealed by individuals' behavior and their demand for associated market goods, e.g., how much more individuals pay for homes in neighborhoods with clean air reveals how much they value clean air, and that the degree to which vacationers change their travel plans when visibility deteriorates at a particular park reveals how much they value visibility. Successful application of this approach also requires that technical measures of pollution concentrations or visibility levels are reasonable representations of the environmental attributes that individuals value and that these measures can be used to identify that part of an individual's behavior attributable to the component of environmental quality being studied.

Although residential property value studies are currently the predominant variation of the market approach, recent work has also used commercial property, wages, recreation travel patterns, and expenditures in an attempt to identify willingness to pay for air quality. These developing approaches are introduced in Section 4.4.

The second group, "contingent market approaches," attempts to elicit values through surveys of how respondents think they would behave if a proposed visibility change were to occur in hypothetical situations. The bidding methods are in this group. In contrast to the market approaches, non-market approaches do not attempt to infer values of a component of environmental quality from observation of individuals' actual behavior in response to a change in environmental quality. Instead they ask the individuals themselves to predict how they would behave or have behaved in response to a change in environmental quality. This approach presupposes that a particular change in environmental quality can be described to the respondents, usually with photographs and verbal descriptions, in a way that corresponds to what their perceptions of the actual experience would be. For example, it is assumed that a photograph of the Grand Canyon obscured by pollution will elicit a response that corresponds to what the response to the actual situation would be. This type of approach also assumes that individuals are capable and willing to predict accurately their response behavior to a hypothetical situation that they may or may not have ever actually experienced.

Bidding methods represent the predominant contingent market approach currently in use to estimate benefits of visual aesthetics. Other contingent market approaches being investigated include some types of travel cost methods, ranked attributes and voting schemes. These developing approaches are introduced in Section 4.4.

4.2 Bidding Methods

4.2.1 Introduction to Bidding Methods

The term bidding methods is used to describe a set of survey approaches typified by the iterative bidding approach. These approaches are often referred to as contingent market approaches because the values received are contingent upon the hypothetical market established in the survey instrument. The iterative bidding approach was first pioneered for outdoor recreation demand analyses by Davis (1963). Since then it has been used to estimate values relating to wildlife and recreation, risks of nuclear power plant accidents, power plant siting, television demand, beach use, urban noise, water pollution, strip mining impacts, and for air quality aesthetics and health impacts, among others.[1]

The use of the iterative bidding technique to estimate values associated with changes in air quality was initiated by Randall et al. (1974) in the Four Corners area. Additional studies followed including Brookshire et al. (1976) and Rowe et al. (1980) also in the Four Corners area; Brookshire et al. (1979) in the Los Angeles South Coast Air Basin; and EPA (1981), for estimating values related to the Grand Canyon and Southwest parks for respondents in selected cities across the United States.

In bidding techniques, respondents are given information on current and proposed or potential alternative levels of visual quality at a particular site. They are also given hypothetical markets which describe how payments are to be made or received by the respondents related to changes in the air quality level. Next they are asked to bid their maximum willingness to pay (WTP) or minimum willingness to accept compensation (WTA) to incur or prevent the change. If a degradation of visibility is proposed, respondents might be asked their WTP to prevent this change or their WTA to allow the change. Similarly, for a proposed visibility improvement, respondents are asked their WTP to fund the change or WTA to forego the change. For example, respondents might be presented the following hypothetical situation: "If visibility were to change from level A to a higher level B," and a market mechanism, "using a surcharge on your utility bill which would go to a fund to prevent visibility degradation," and in an attempt to receive a measure of the consumer surplus associated with that change, "what is the maximum you are willing to pay each month on your utility bill to achieve the increase in air quality from level A to level B?" Because the valuations may vary with small nuances in the application of this technique, it is imperative that it be carefully designed and monitored.

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[1] A survey of 18 applications of the iterative bidding technique can be found in NUREG (1979).

4.2.2 Theoretical Basis

The bidding method approach is closely tied to the basic theory of consumer valuation. Individuals are perceived as having the ability to make well defined, rational decisions regarding trade-offs among alternatives in order to maximize their own utility. The questions regarding WTP and WTA are attempts to directly reveal the equivalent and compensating surplus measures associated with the proposed air quality change, as shown in Table 4.1. The measures are typically equivalent and compensating surplus measures because the respondent must accept either the current visibility level or the new or proposed visibility level (as shown in Figure 2.8 in Section 2.2.3).

Table 4.1: Correspondence Between Willingness to Pay Measures and Consumer Surplus Measures

	Proposed Change	
Questionnaire Approach	Increased Environmental Quality	Degraded Environmental Quality
WTP Approach	CS	ES
WTA Approach	ES	CS

Use of bidding games requires that certain assumptions be met. First, that individuals value certain aspects of changes in air quality and that these aspects can be determined by researchers and appropriately conveyed to respondents. It must be further assumed that respondents understand the proposed changes and can, and will, accurately determine what their behavior would be under the alternative situations. Abstract economic assumptions are not needed if comparison and aggregation of benefits is to take place according to some simple classification scheme--such as by mean responses of different income class. Generally cross-sectional analysis of bidding method responses and their determinants is undertaken. This effort requires more specific assumptions about how visibility enters the utility function and the use of specific forms of the utility function, such as those presented in Section 2.5.

Property Rights in Bidding Methods

The correct choice of welfare measures in the application of the iterative bidding approach also depends upon whether or not the individual thinks he has, or is made to think he has, a right, referred to as property rights, to his preferred state of environmental quality and whether the current state is believed to be better or worse than the alternative state. This will influence the acceptability of the hypothetical situation to the respondent. Considering an air quality degradation, a respondent who believes he has a property right to the higher level of air quality may feel that the liability to compensate those affected or to fund improvements lies with the polluters. Consequently he may reject the alternative markets as inequitable. As shown in NUREG (1980), four alternative situations can be considered--the maximum willingness to pay to avoid a "bad" (WTP^B), or to acquire a "good" (WTP^G), and the minimum compensation necessary for the individual to accept a "bad" (WTA^B) or forego a "good" (WTA^G). The approach must account for the desirability of the proposed change and the implied or believed property rights of the individual, as shown in Table 4.2.

Table 4.2: Appropriate Iterative Bidding Measure of Welfare Changes

	Property Right	
	Preferred State	Less Preferred State
Proposed State is Less Desirable	WTA^B	WTP^B
Proposed State is More Desirable	WTA^G	WTP^G

WTP^B and WTA^G are equivalent measures.
WTP^G and WTA^B are compensating measures.

4.2.3 Application

Bidding methods have two principal components: the survey procedure and the survey instrument. "Survey procedure" refers to where the survey takes place, sampling procedures and how questions are presented to respondents. "Survey instrument" refers to what is commonly called a questionnaire, or the paper containing the questions to be answered by the respondents.

The design of the survey instrument, which is the most important element of any bidding method, is greatly influenced by the survey procedure employed. Typically, personal interviews, guided interviews or questionnaires are used. In the personal interview, each respondent is questioned individually by the enumerator. This allows the most flexibility in question design and enumerator/respondent interactions, clarification of definitions, explanation of concepts, and the like. They are also the most expensive. Guided interviews involve one or more subjects who read and answer some of the questions on their own, in the enumerator's presence. In the questionnaire procedure, the survey instrument is completed by the respondent alone. These require the most amount of design control and limitations. Other aspects of the survey procedures are discussed in Section 4.2.6 below.

The concepts and procedures of bidding method survey instruments, and the hypothetical situations involved, may be unfamiliar to respondents, and therefore great care must be taken to insure that the survey instrument is concise and well defined, yet fully informative. Survey instructions which are ambiguous or have ill-defined sections will decrease the ability of respondents to accurately respond to the proposed situation. On the other hand, survey instruments which are too long often have poor response rates. The respondents who do complete the instrument may do so from a feeling of obligation, but they may not feel obligated, or they may not be able, to continue responding accurately (response fatigue). Therefore, a carefully defined survey instrument is central to the success of this approach to valuing air quality.[2]

Bidding method survey instruments typically have the following sections: (1) a general introduction and statement of purpose; (2) introductory non-valuation questions; (3) scenario development and market definition; (4) bidding or valuation questions; (5) evaluation of problem bids; and (6) special options, closing questions and remarks. The remainder of this section examines the purpose and types of approaches used in each of the six sections of the questionnaire. Sample questionnaires from actual experiments and suggested wordings for Water Resource Council projects may be found in Appendix 1.

General Introduction and Statement of Purpose

The introductory statements serve to identify the research organization, the purpose of the survey, why the respondent has been chosen, and how long the survey will take. These comments should be truthful and to the point. The wording and the enumerator must start out and remain neutral throughout interview. Enumerators should appear not to have a vested interest in anything but the accuracy of the results. The introduction should convey to respondents that accurate answers are of value to the research project and ultimately to the respondents themselves so as to increase their incentive to respond accurately; it should also initiate rapport and provide accurate information so that the respondent will not later on feel mislead as to the intent of the questionnaire or the necessary level of effort or time. A sample introduction might read as follows:

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[2] For any government-sponsored research all questionnaires administered to more than 9 individuals are subject to Office of Management and Budget (OMB) procedures for questionnaires to insure they are not offensive or unnecessary. OMB questionnaire guidelines and procedures can be found in OMB circular 40.

> Good morning/afternoon. My name is ______________ (present ID). I am from the Western Policy Research Institute in Denver, Colorado. We are doing research to examine the trade-off between recreation, industrial development and air quality in this area. In order to accurately perform this research, we need a cross-section of opinions. Would you be willing to spend ten minutes to answer some questions about your recreation patterns and air quality in this area?

Introductory Non-Valuation Questions

Introductory non-valuation questions generally gather useful socioeconomic characteristics of the respondents, establish existing behavior, or simply determine whether the respondent is appropriate to be included in the sample. For example, a survey of how air quality at recreation sites will alter recreation location patterns may first need to establish existing recreation location patterns and link them to existing air quality levels. Again, questions should be limited only to those necessary to evaluate responses and implement benefit assessment models. Sensitive, threatening or embarassing questions, such as education and income, should not be asked early on, since those concerning the accuracy of subsequent responses (Locander 1977). Questions such as On a 1 to 5 scale, are you an environmentalist or developer? or Are you a member of an environmental organization? may have merit in the analysis, but if asked early on the questionnaire may tend to create a situation where the respondent later feels obligated to bid differently from how he might have bid had he not been asked these questions.

Scenario Development and Market Definition

Scenario development and market definition is the most critical aspect of bidding method survey instruments. This section must carefully present information on alternative situations, payment procedures definitions of visual impairment and the like. In essence, before respondents can reveal the value they associate with proposed visibility changes they must clearly understand, as journalists say, "the who, what, where, how, when, and why" of the story. To do so researchers must first determine how air quailty attributes relate to physical measures of pollution, what attributes of air quality are important to individuals and how best to convey these attributes to respondents. This is an area where economists must interact with social and physical scientists (see Chapter 3). Before a contingent market survey is performed it may also be desirable to first conduct a survey that determines those attributes of the potential impacts of importance to affected individuals (for an example see US NPS 1980). If all important attributes of air quality conditions can be defined and presented in sufficient detail, all respondents will be able to accurately perceive the changes that are being proposed.

Verbal or written descriptions of conditions alone may be satisfactory where alternative scenarios can be clearly defined by the enumerator and understood by respondents. This is possible for many activities and environmental amenities such as wildlife stocks, but descriptions alone are not satisfactory for the characterization of air quality conditions. On-site presentation of conditions, while most accurately reflecting one level of air quality are also the most difficult to control and expensive to administer. The conditions, including visual range, contrast, cloud cover, and the like, must be continuously monitored to accurately account for variations in the valuations received (see Section 2.4 above). As a result, pictorial representations of alternative air quality scenarios using photographs, slides, and motion pictures coupled with verbal descriptions and maps have become the standard mechanism for displaying alternative scenarios of air quality. The techniques used for pictorial presentations are described in Chapter 3.

The scenario development should include some or all of the following characteristics:

1. A description of the elements of the air quality for the situation in question and how it is proposed to change, including location, intensity, duration, frequency, time of day, plume blight or regional haze, etc. (each of these is relevant to EPA promulgated regulations concerning significant changes in air quality). Air quality is a multifaceted, ever-changing environmental good. The more clearly characteristics and changes can be mutually understood, the better the evaluation of the benefit analysis will be. It should also be made clear whether an impact is to occur at one site or across the whole region.

2. Some indication of why and how these changes affect the individual respondent, such as visibility aesthetics in the recreation experience or at his place of residence, the health effects, etc. Changes in visibility and health aspects of air quality may occur independently but may not be believed to be independent by respondents, and therefore it is important to key the respondent on the appropriate aspect of interest in order to isolate its effects and benefits.

3. Descriptions of why current or potential air quality levels may occur. This includes automobile exhaust, better emission control devices on large new or old power plants in the region, and the like.

4. How changes might take place, how they will be paid for, and when and how they will be implemented, such as a monthly utility bill increase to pay for addition emission control devises, or a state fund to increase mass transit financed through increased automotive sales taxes.

To be successful the scenario development must be informative; clearly understood; realistic by relying upon established patterns of behavior and legal institutions; have a uniform application to all respondents; and, hopefully, leave the respondent with a feeling that the situation and his responses are not only credible but important. The pictorial representations of alternative scenarios, if used, should illustrate the important air quality attributes and problems relevant to the study area, including discoloration and visual range in directions of interest. Current and alternative situations should be clearly differentiated.

The frequency of occurrence of alternative levels of air quality has emerged as an important concern in visibility benefit analysis. In the past, alternative scenarios have been presented with each depicting one level of air quality as "typical." However, the value an individual places upon improving typical visibility from some level D to a higher level C may depend upon how often D can still be expected to occur in the new situation as well as how often even higher levels of visibility, B and A, can be expected. The damage to an individual who goes to a national park the only day it is totally polluted may not be offset by the value to another individual who goes on the only perfect day. There may also be benefits from reduced uncertainty as to which air quality level will be encountered.

There are several methods to present and evaluate the effect of the frequencies of encountering visibility levels other than the typical level described in any particular scenario. First, one might present some form of probability distribution for each level of air quality in each scenario (5 days of A, 20 days of B, and 5 days of C per month) where the distribution is changed across respondents. Unfortunately, this may overload the respondent with more information than he can retain and respondents may end up only concentrating upon the mean levels. (This is a testable hypothesis.) Second, respondents may simply be told to compare a situation where B is typical, with some A and some C, but no D, to a situation where C is typical, with some A, B, and D, or some suitable combination.

Perhaps the most appropriate method to account for the impact of different frequencies of alternative levels of visibility is to estimate the benefits associated with changes to each level, as in the second approach described, and then insert these values into a joint probability distribution function of the expected rates of occurrence of the alternative visibility levels and visitation rates by time of day and day of year. This could be done in the estimation process after the survey. For example, if, in one scenario, 50 percent of visitors or residents could expect with certainty an air quality change for some level C to level B, 25 percent could expect change from C to A, and 25 percent could expect no change, then the appropriate value of achieving this scenario, if the individual were risk neutral, would be .5 * (value of C to B change) + .25 * (value of C to A change).

The following is a sample scenario development from the South Coast Air Basin study (Brookshire et al. 1979).[3]

> Here are three photographs representing average levels of visibility for the three different regions of the Los Angeles Area shown on this map. Picture A represents poor visibility; Picture B represents fair visibility; and Picture C represents good visibility.
>
> Public officials are strongly considering the possibility of trying to reduce the levels of emissions throughout the Los Angeles Area. Such action could require additional funds which might be generated by (a monthly charge, an extra charge in your utility bill) for as long as you live in the Los Angeles area. These funds will be used to help finance air quality improvements in the Los Angeles area. (Page 140.)

The aesthetic valuation component of the above scenario development for areas with poor visibility continues with:

> The Los Angeles area has some very beautiful background scenery. Because of automobile and industrial emissions, there is a haze which reduces and distorts the ability to see this scenery. This means that many people have to leave Los Angeles and travel long distances to be able to enjoy views which could be visible from their homes if these emissions were reduced.

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[3] The lists in parentheses represent alternatives which are randomly preselected to test their influence on the valuation process.

> As indicated by the map, you live in an area which has been classified as having poor air quality relative to the rest of the Los Angeles area. Picture A represents the visibility level which typically occurs in your area. I am only interested in how you value being able to see long distances.
>
> If the level of emissions could be reduced in the Los Angeles area so that visibility conditions would be represented by Picture B instead of A, not only in the B area but also in your area, and if the air would be cleaned up to this level in (2, 10) years, would you pay (a monthly charge, an extra charge in your utility bill) of ($1, $10, $50) for as long as you live in the Los Angeles area? (Page 141.)

Bidding or Valuation Questions

The next section of the bidding procedures attempts to elicit values for alternative levels of air quality or for changes in air quality. Respondents may be presented with different bidding schemes, including the iterative bidding process, selection of intervals, or the selection of specific alternatives. The iterative bidding procedure involves a situation where, perhaps, an increase in air quality is proposed from some level C to higher levels B and A. Answers are elicited in terms of yes or no to questions expressed in the form, Would you pay amount X...? A yes answer leads the enumerator to raise the amount and repeat the question, perhaps repeatedly until a no answer is obtained. At this point the amount is reduced until a yes answer is again obtained. The largest amount that elicited a yes answer is recorded as the maximum willingness to pay. WTA approaches substitute "willingness to accept X" for "willingness to pay X" and lowers rather than raises the amounts upon receiving yes answers and vice versa for no answers. Respondents tend to catch on quickly to the iterative bidding procedure and cut it short by stating their maximum WTP or minimum WTA for a proposed level or change in air quality. The one drawback to this iterative procedure is that it requires the personal interview format, which is the most expensive to administer.

Alternative approaches to the iterative bidding procedure include simply asking the respondents their maximum WTP or minimum WTA and presenting dollar intervals to choose from, dollar options to choose from, or a fill-in-the-blank procedure. These non-iterative bidding approaches are more amenable to the guided interview and mail questionnaire surveys but may suffer from increased measurement error because the most precise bid possible may not be elicited.[4]

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[4] Mail questionnaires with interval choices have been applied repeatedly for wildlife valuations (see Hammack and Brown 1974 and Brookshire et al. 1977). The later study found no statistically significant difference between the mean bids between a personal interview iterative bidding approach and an interval approach mail questionnaire.

The bidding questions may address alternative levels of visibility or changes in the level of visibility. For example an enumerator might ask, "If you were to still spend (N) days per year recreating at [selected park] what would be the maximum entrance fee you would be willing to pay per day if visibility were as depicted in situation [A,B,C]?" In this case the question would be asked for all three levels with the difference in the maximum willingness to pay across levels representing the value (welfare measure) of changes in air quality.

Questions which directly elicit the value of changes in visibility are asked slightly differently. For example, if some air quality scenario C is characterised as the existing level an enumerator might ask, "Would you be willing to pay $X per month on your utility bill to finance emission control which would result in air quality level A (a higher level) rather than C?" Using the iterative bidding approach the amount $X is again varied until the maximum WTP or minimum WTA is determined for the proposed change. There is a pitfall in this approach to valuing changes in air quality that must be avoided. If a respondent does not perceive C as being the current level of air quality, but rather perceives some lower level, D, as being the current level, care must be taken to insure the bids received do not include the value of the change from level D to C as well as from level C to A.

There are several other aspects to the process of eliciting bids, each with variations in application. The type of payments are typically accounted for in dollars per unit time; however, expenditures of time, travel or moving costs are also potential units of measures convertable to dollar equivalents. Payment procedures must also be considered. Respondents may be presented with one of many schemes as to how actual payments would be made if the plan were implemented, including everyone paying equally, everyone paying equally at the mean value estimated for the population, paying their bid, paying a proportion of the total depending upon their own bid, and the like. The first two approaches have been used more frequently.

Payment procedures should be designed to be viewed by respondents as fair and ethically sound. Bids should also be presented as payments, not contributions. Respondents should have a clear understanding that if they were not willing to pay a certain price they would have to go without the good. Wording such as "would you be willing to pay..." may be misinterpreted as an appeal for voluntary contributions.

"Payment vehicle" refers to the method through which payments are to be made. The most prevalent have been user charges, such as entrance fees, license, and purchase fees; utility bill increments; and sales taxes. The payment vehicles should be carefully pretested and include a neutral vehicle, such as a trust fund devoted entirely to providing the good. Vehicles which generate emotional responses on related issues should be avoided.

Finally, additional information may be given to increase respondents' understanding of the market and increase the accuracy of their bids. This may include tables which indicate what a monthly payment sums to over several years, or how each 1 percent of sales tax relates to dollars spent by income bracket.

Two sample procedures are presented below. The first, from Brookshire et al. (1976), is an example of an iterative bidding procedure.

> First, let's assume that visitors to GCNRA (Glen Canyon National Recreation Area) are to finance environmental improvements by paying an entrance fee to be admitted into the recreation area. This will be the only way to finance such improvements in the area. Let's also assume that all visitors to the area will pay the same daily fee as you, and all the money collected will be used to finance the environmental improvements shown in the photos.
>
> Q6. Would you be willing to pay a $1.00 per day family fee to prevent Situation C from occurring, thus preserving Situation A? $2.00 per day? (increment by $1.00 per day until a negative response is obtained, then decrease the bid by 25 cents per day until a positive response is obtained, and record the amount).
>
> Q7. Would you be willing to pay a $1.00 per day fee to prevent Situation B from occurring, thus preserving Situation A? (repeat bidding procedure).

The second is an example of a value selection approach.

> Clearly, everyone desires cleaner air; however air quality improvements entail considerable expenditures. Let us propose a mechanism to continue to finance improvements in visibility. Suppose the method used to finance continued emission control would be through additional monthly charges on your utility bill and everyone would pay the same amount.
>
> Q1. With this in mind what is the maximum monthly amount you would be willing to pay each month to attain the improved visibility level B rather than the current level C (enter #1 next to the highest amount in the table below).
>
> Q2. What is the maximum amount you would be willing to pay each month to expect the improved visibility level A rather than the current level C (enter #2 next to the highest amount in the table below).

$ .00 ______
$ .50 ______
$ 1.00 ______
$ 1.50 ______
$ 2.00 ______
$ 2.50 ______

$ 3.00 ______
$ 4.00 ______
$ 5.00 ______
$ 6.00 ______
$ 7.00 ______
$ 8.00 ______
$ 9.00 ______

$ 10.00 ______
$ 15.00 ______
$ 20.00 ______
$ 25.00 ______
$ 50.00 ______
$ 75.00 ______
$100.00 ______

Evaluation of Problem Bids

In many instances, respondents to bidding method questionnaires misrepresent their valuations by giving false zero bids, refusing to give finite bids, or simply refusing to respond to questions posed to them. These bids, or rejection of the bidding process, do not reflect the true valuation of changes in air quality and must be distinguished from "true bids" for use in policy analysis. In many cases problem bids related to questionnaire design can be eliminated through careful pretesting. In both the pretest and survey respondents should be queried as to the intent of any problem bids by presenting alternatives as to why these bids may have been given. Sample responses and interpretations of zero bids are provided in Table 4.3. Similar responses for infinity bids could be developed. If the received bid is truly a rejection of the procedure, alternative approaches may be attempted.

Special Options, Closing Questions and Remarks

At this point in the survey special options and closing questions may be presented to respondents. Special options may include attempts to validate or analyze the values previously received, to separate out aesthetic values from health values, or simply to ask special policy questions related to the specific site. Final questions may be less restrictive in content or more open ended, such as the respondent's environmental stance, his income, or whatever is deemed necessary to insure accurate modeling and evaluation of responses.

Table 4.3: Interpretation of Zero Bids

Response Alternative	Interpretation
a. The change in air quality is not significant.	True zero bid.
b. It is unfair to expect the victim of the damage to have to pay the costs of preventing the damage.	Rejection of bidding game.
c. The methods of payment are not satisfactory.	Vehicle rejection.
d. The money collected would probably be used ineffectively.	Rejection of bidding game or payment vehicle.
e. Other (please specify).	--- ? ---

Source: Blank et al. (1977).

4.2.4 Strengths of the Bidding Questionnaire Approach[5]

Contingent market valuation techniques, including bidding methods, offer bright prospects for analyzing any important issue or value associated with air quality. As long as a credible situation and market mechanism can be developed and the survey instrument is carefully designed and pretested, the researcher can obtain reliable and defensible value estimates.

The strengths of this approach are many, but probably the most important is that the technique is both well grounded in economic theory and flexible in application. The approach can be applied to obtain separate activity, option and existence values, both on-site and at alternative locations, while it is virtually impossible to employ market approaches to elicit option and existence values for changes in air quality. Carefully designed survey instruments can be applied to evaluate the lasting or temporal effects of plume blights and of regional haze at both national parks and in urban centers as long as these impacts can be conveyed to respondents in a manner they can understand and relate to. Impacts at any one site or across an entire region can be examined with bidding methods. Separate aspects of air quality, such as aesthetics and health, may also be individually valued.

Both potential increases and decreases in air quality may be examined before a change has occurred. The contingent market approaches allow the design of trade-offs which are credible but may never even occur in actual markets due to legal or political constraints. In essence the approach is not limited by the appropriateness of available data or other problems in market data.

Another strength is that data are generated that conform to an economic model, eliminating the necessity to develop a model with limiting and special assumptions so it may be applied to some existing data set. This often eliminates special prior theoretical assumptions which are sometimes necessary to apply market data to visibility benefit models. Bidding methods also virtually eliminate the worry about complications of market imperfections and transactions costs, which in many cases may overwhelm the application and accuracy of market approaches. Another strength of these approaches is their ability to allow the researcher to account explicitly for, and to investigate, the impact of property rights structures.

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[5] Other useful reviews of the strengths of air quality contingent market approaches are found in Brookshire et al. (1979). It should be noted that many of these strengths and weaknesses apply to all non-market, or contingent market, approaches.

4.2.5 Weaknesses of the Bidding Approaches

Bidding methods have several important problems. The most important is what sociologists and survey psychologists deal with in interview studies--designing questions so as to minimize perception errors and biased responses. The second problem area is desiging and implementing an effective survey procedure, and determining the appropriate functional relationships to evaluate responses. Due to the unique importance of questionnaire design issues to the application of bidding methods, they are discussed at length below. Discussion and directions for survey procedures and data analysis are provided in Section 4.2.6.

Perception errors and biases may be inherent in the survey instrument design. Bidding methods ask respondents to reveal consumer surplus measures for hypothetical situations often not faced in a market place. Therefore, only perceptions, or estimates of their "true" values and behavior within the context of the hypothetical situation and market, as they perceive it, can be reported. The reported values may well reflect the respondents "true" values, estimated with a great deal of uncertainty, and subject to the influences inherent in the design of the survey instrument. These influences decrease the accuracy of responses and may yield potential biases in the valuation process. Minimizing and eliminating these problems greatly enhance the usefulness of contingent market approaches to the researcher. The following discussion covers five particular types of problems that may occur--hypothetical bias, strategic bias, information bias, contingent market rejection and problem bids, and other problem biases. Tests for the existence and magnitudes and actions that may be taken to minimize their impacts on the accuracy of the valuation process are also presented.

Hypothetical Biases

The term hypothetical bias refers to any inaccuracies or biases in respondents' answers because they are not revealing actual behavior but rather stating intended behavior in a hypothetical situation. As many economists have pointed out, if respondents believe a situation to be fictional, their responses often will also be fictional and therefore will not reflect their true preferences and behavior.

The design of bidding method survey instruments has the potential for hypothetical bias problems. Respondents are presented hypothetical scenarios and asked how their intended time and budget allocations would change if the scenarios occurred. There are several reasons for inaccurate responses to these hypothetical questions. First, respondents may be unable to visualize themselves in the hypothetical situation with which they are presented and cannot accurately determine what their actual behavior would be. For example, a non-hunter might have great difficulty with a question such as, If you desired to hunt elk and could expect a 40 percent chance of successfully bagging an elk, would you be willing to pay $X for the hunting license? because the situation would not be realistic or relevant to him.

Second, people may tend to be more conservative and to more carefully account for time and budget constraints when deciding to allocate real dollars and time than when responding to hypothetical situations. It may well be the case that a survey instrument can obtain consistent positive values of some amount, say $5, for nearly anything if the respondents do not believe they will actually have to pay the stated amount, or if the situation lacks credibility. For example, how credible is it that park entrance fees will be increased to pay for environmental improvement at regional power plants, or how credible is it that utilities will raise all consumers' monthly utility bills by a lump sum amount to pay for increased emission controls?

The question of hypothetical bias is whether the contingent answers are an accurate reflection of what would occur if the defined market did exist. There is evidence that the hypothetical bidding method survey instrument does generate inaccurate and biased responses. One study (Bohm 1971) compared the effects of several alternative bidding and payment schemes upon the valuation procedure for public television. In several of the alternatives respondents were actually given money to spend and presented with several different payment schemes, such as all pay equally or paying your stated bid. Another group was asked how much they would be willing to pay rather than having to actually pay for public television. These WTP bids were statistically significantly larger than the bids of those who actually paid. In another study, Bishop and Heberlein (1979) found that stated willingness to pay for goose hunting licenses (WTP^G) was much smaller than actual cash offers accepted to forego hunting (WTA^B). These findings must be tempered with the expectation that WTA^B would exceed WTP^G measures. A more appropriate comparison would have been to compare the same measure in actual and hypothetical situations. In a third effort Brookshire, Randall and Stoll (1980) found that if respondents felt either the situation or their bid lacked credibility they tended to decrease their bids. In summary, hypothetical biases and inaccuracies seem to exist in bidding methods, but the size and direction is unknown and is probably unique to each application.

Another indicator of the weakness of the hypothetical approach is the often high variability of the values received. In several air quality studies (Brookshire et al. 1976; Randall et al. 1974; and Brookshire et al. 1979) less than 10 percent of the variation in the bids received could be accounted for by socioeconomic variables or by changes in the levels of visibility.

Biases and inaccuracies in hypothetical survey instruments can be minimized if situations which are realistic and credible can be developed by researchers and accepted by respondents. Sociologists and public opinion researchers have built up a substantial body of literature conveying methods of making survey instruments more reliable, including the use of concrete elements of realism and credibility (see Crespi 1971; and Erskin 1972). Psychologists Ajzen and Fishbein (1977) have shown that to maximize the relationship between stated intended behavior and actual behavior, the hypothetical situations should correspond to actual situations and behavior in terms of action, context, target, and time frame. Also, knowing respondents beliefs is the best aid in predicting behavior. A well designed and pretested iterative bidding survey instrument should attempt to meet these conditions. The major problem area is the context: if the contingent market context does not relate to real world situations, uncertainty and measurement error may increase. The problem here is that the real world often does not have effective markets in which preferences for air quality may be reflected in the manner that individuals may desire for any specific application, such as emission control funds at a national park.

Biases and large measurement error in hypothetical markets may not be any more serious than in market approaches if the hypothetical scenario is credible. The accuracy of values that are reflected in market data is also subject to limited information when individuals make choices and is confounded by market imperfections and transaction costs. In fact, in a carefully designed contingent market, respondents may state intended behavior which is based upon more, and perhaps more accurate, information than that available in real markets.

Strategic Biases

Strategic biases occur when respondents systematically overbid or underbid relative to their true values. Because these bids are not equal to their "true" values, they are biased estimates of value. There are two common incentive structures for over or underbidding--attempting to "free ride," and attempting to influence the study results to an outcome more favorable to a position the respondent supports.

"Free riding" refers to the concept that a consumer believes he is better off by not paying for the provision of a public good while at the same time enjoying its consumption because others have paid for its provision.[6] An individual attempting to free ride would bid zero even when visibility changes have a positive value for him.

An individual may overstate or understate his true values in an attempt to strategically affect the outcome to a position he supports. For example, a very strong supporter of air quality improvements may overbid his true preferences to bias the results of the study in his favor, while a developer may underbid for the same reasons.

The ability to effectively strategically bid can be tied to the proposed payment scheme.[7] For example, respondents may be more inclined to attempt to free ride under a scheme where everyone is to pay his stated amount rather than if everyone is to pay an equal share of the total costs. Bidding may also be affected by the credibility of the payment scheme. If respondents do not believe the payment scheme will actually be instituted, but that these results will be used for some cause (respondents must ask themselves who plans to use this and why), there is an incentive to bias the results to their advantage.

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[6] The free rider problem dates back to the seminal work on public goods by Samuelson (1954) and respresents the classical argument of why markets fail to provide public goods, as well as why valuation methods are expected to reveal biased values.

[7] See Kurz (1974) and Bohm (1971). Several articles on related topics can be found in the 1977 issue of Public Choice.

A number of studies have examined the effect of payment schemes on the bids. Bohm examined six alternative payment schemes for a publicly provided commodity (public television) that were designed to elicit strategic responses. Bohm's analysis concluded that there was no significant difference between any of the payment schemes except when no formal payments or decisions were to be based upon the results. In this case the bids were significantly higher--a problem more closely related to hypothetical bias, discussed earlier. Scherr and Babb (1975) examined the desire to free ride using three payment schemes to reveal valuations for two public goods--a concert and a library fund. No evidence was found to reject the hypothesis that any scheme inhibited free rider behavior. In a study of aesthetic damages from coal mining in Kentucy, Randall et al. (1978) found that three different payment mechanisms, which theoretically should have yielded equivalent mean bids, yielded significantly different results. Finally, in several laboratory experiments, Vernon Smith (1977, 1980) found that free riding and strategic behavior can be avoided by the choice of vehicles and decision making processes.

Two air quality studies in which iterative bidding techniques were used have examined the potential for strategic behavior. In the first, Brookshire et al. (1976) posited that if a respondent desires to effectively influence the study valuations to a position that reflects his value, he must possess a great deal of information as to the average bid of other respondents, the strategic behavior of other respondents, and the sample size. The study asserted that the existence of strategic bids will result in a flattened distribution of actual bids relative to the normal distribution. No formal empirical tests were conducted.

In the second such study, Rowe et al. (1980a) attempted to test specifically for strategic bias. While many other problems were detected, only obvious strategic bids were detected. In this study, half the respondents were provided false information about the mean bid of other respondents before they bid. All respondents were then asked their environmental stance after bidding, the hypothesis being that environmentalists would be more apt to attempt to increase the mean bid artificially by overbidding their own "true" value, while developers would act in just the opposite manner. No statistically significant strategic influences were found after deleting obvious problem bids, such as respondents who were openly giving false answers or were not cooperating; deleting all bids greater than ten standard deviations from the income adjusted means, as such bids are suspect because with most any statistical distribution these values would occur less than once per several hundred observations; and after deleting bids determined to be free riders (using Table 4.3 above).[8] Next, approximately one third of the respondents in the sample were provided information on the sample mean bid after they had bid. Only one respondent altered his bid and that was to the supposedly lower overall bid.

The evidence to date indicates that strategic behavior related to the free rider problem may be detected and that behavior aimed at affecting the overall valuation procedure is not a statistically significant influence in the bidding methods when obvious problem bids are eliminated.

Information Biases

Information may be explicitly and implicitly conveyed to respondents, which, given their uncertainty about their true valuations, may influence and bias the revealed valuations. For example, in Rowe et al. (1980a) selected respondents were told a supposed mean value received thus far that was very low. Individuals receiving this information bid significantly less than the other respondents. This suggests that if individuals are given sufficient information, whether it is or is not valid, and their true bid exceeds the stated mean bid they may be influenced to believe their bid is "incorrect" or they will exhibit a form of the classic free-rider behavior and bid a different amount than their maximum WTP. The South Coast Air Basin study (Brookshire et al. 1979) also found instances when the order of the presentation altered the bids in a statistically significant manner.

Iterative bidding questionnaires are potentially subject to another type of information bias induced by the suggested starting bid. The procedure asks for yes and no answers to questions like, Would you be willing to pay x....? In situations where the respondent is uncertain of his valuation or has a great deal of problems with the contingent market, the starting bid may have a strong informational content as to his "expected" bid. For example, starting values of $10 and $100 may suggest different expected final bids are to be received. A pretest for starting bid bias can provide very useful information about the quality of the contingent market process.

A second problem related to the starting point is that if the bidding process is methodically implemented the respondent may become bored and cut the process short at a value other than his maximum WTP, though in most iterative bidding surveys it has been found that many respondents quickly adapt to the process and cut it short by jumping to their final values.

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[8] The study also noted that in the situation depicted the respondents were to pay for most or all of the abatement costs as well as receive most or all of the benefits. If respondents, as a group, were paying a minority of the costs but receive all of the benefits, they may bid strategically to increase the total paid by the paying majority (possibly in another state) to increase the unpaid for benefits they receive.

The same starting point information bias may occur in interval or numerical selection versions of the bidding technique described. In these cases, the clustering and range of intervals or dollar values to choose from may suggest and influence the final values elicited.

Only five iterative bidding studies to date have reportedly tested for starting point information biases (Rowe et al. 1980, Brookshire and Randall et al. 1978, Thayer 1981, Randall et al. 1978, and Brookshire et al. 1979). Rowe et al. (1980a) found starting point bias for the valuation of air quality in the Farmington, New Mexico, area. The South Coast Air Basin study (Brookshire et al. 1979) also found a starting bid problem in about one-sixth of the alternatives bidding situations. No other studies of visibility using bidding methods have tested for starting point bias. The exact nature of the starting point bias tests were not reported in two of the other three studies and cannot be evaluated.

Other influences may be imparted by the enumerator. All surveys are affected by the interpersonal dynamics of the enumerator/respondent relationship. The critical element is that the enumerator must remain neutral and appear interested only in the accuracy of the results. A carefully designed and pretested questionnaire will test for and minimize each of these information biases.

Contingent Market Rejection and Problem Bids

Bidding questions for changes in air quality are not always well received by respondents for many reasons. These may include rejection of the hypothetical scenario, rejection of the payment mechanism (utility bill, sales taxes) or payment scheme (all will pay equally versus the individual will pay his own valuation), rejection of the implied property rights or liability rules presented in a situation or, rejection for moral and ethical reasons. Payment vehicle problems are a classic example of a contingent market rejection that may occur. Respondents may object to the use of utility bill increments, payroll deductions, or sales taxes. Both the South Coast Air Basin study (Brookshire et al. 1979) and Rowe et al. (1980a) found that for about one-third of the bidding situations the payment vehicle was a statistically significant influence on the bids received for visibility changes.

Rejection and protest bids have varied from 20 percent (Brookshire et al. 1976) to 50 percent (Randall et al. 1979, Rowe et al. 1980, and Brookshire and Randall 1979) for specific applications of the bidding technique. In these cases, respondents' true values remain unknown and unaccounted for. If this non-cooperation is not random across respondents, it will bias the valuation process.

Another reflection of problems in the bidding method scenario developments has been that the WTA payment bids are often considerably higher than WTP bids compared to what theoretically is expected from income effects alone. For visibility studies Rowe et al. (1981) found the ratio of WTA to WTP bids ranged from 4 to 14. Other non air quality bidding technique studies have resulted in WTA measures of up to 12 times larger than WTP measures.[9] This is an area of particular concern for the future development of the bidding method procedure.

Attempts to obtain compensating surplus measures for proposed environmental degradation have met with the most protest bids. In willingness to accept compensation approaches, respondents are asked their minimum willingness to accept payment for decreasing air quality. Respondents may believe they have a right to the higher preferred level of air quality and reject being "bought off," either for their own sake or for the sake of the community as a whole. It may also be the case that they are giving WTA^B bids based not upon their own ability to pay (income) but rather upon the ability to pay of the suggested payee, such as a utility company. In these cases respondents often reject bidding or give very large and infinite bids. It is also possible that the compensation may simply need to be very large to offset losing the wealth associated with the perceived ownership of the higher level of air quality.

Respondents who believe that they have a right (referred to as property rights) to the current level of air quality may also reject the concept of increased payments, for example on their utility bill, to prevent degradation of air quality, often seeing this as a "victim pays" concept and feeling that the liability to fund pollution control lies with the polluter. Rejection of this type occurs considerably less often, since many respondents realize that the cost of utility-financed emission control devices are often passed on to consumers.

Other Potential Problems and Biases

Other biases and problems are, and will continue to be, revealed as more studies are undertaken using the bidding techniques. One such potential problem is that respondents may be willing not only to make or take payments representing the dollar value of a proposed change in visibility, but they may also desire to change locations, rates of participation in activities, timing, or take other mitigating action simultaneously.

Few bidding methods specifically allow for these simultaneous activities, although there have been recent efforts to incorporate this information (Thayer 1981; Blank et al. 1978). Another way to minimize this impact is to validate results through the use of other approaches, such as the household production function approach or hedonic approaches.

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[9] See NUREG (1980) for a survey of the bidding methods in several alternative applications. Rowe and Blank (1981) have examined several arguments for the large differences in WTP and WTA empirical measures and the implications for measure selection and application of benefit estimation techniques.

Another potential problem, particularly in urban locations, is the inability to separate out aesthetic from health values associated with changes in air quality. An example of how this might be minimized by carefully defining the good and focusing the respondent's attention can be found in the South Coast Air Basin study (Brookshire et al. 1979).

4.2.6 Survey Procedures and Post Survey Data Analysis

Survey methods used to obtain and analyze data can be as influential upon bidding method results as is the choice of economic benefit measures and their application and have, heretofore, not received sufficient attention. Survey procedures entail a great deal of effort and planning, as illustrated in Table 4.4. First, questionnaires must be formulated and designed, as has been described above. Interviewers must be carefully selected, trained and quality controlled to insure that they are effective and neutral in their approach. Interviewers who reveal strong attitudes about air quality to respondents or interviewers who are timid or have presentation problems can inadvertently bias, or worse, actually falsify the results they obtain. The survey effort must also consider the sampling procedures to be used; costs and timing limitations, interview procedures and coordination; the establishment of trouble telephone lines, contacts with local officials and the like; and finally, handling and analyzing the data received.

This section provides discussion and guidance for selected issues which influence the effectiveness and costs of the bidding method or other contingent market survey procedures, and samples used to estimate benefits.[10]

Table 4.4: Steps in Survey Research

1. HYPOTHESIZING--deciding what it is you want to study.
2. DESIGNING--establishing the procedures and methods to use.
3. PLANNING--figuring materials and personnel needed.
4. FINANCING--arranging support for the survey.
5. SAMPLING--choosing which people are to be interviewed.
6. DRAFTING--framing the questions for use in the field.
7. CONSTRUCTING--planning the format of the questionnaire.
8. PRE-TESTING--determining whether the questions elicit the data desired.
9. TRAINING--teaching interviewers how to gather information correctly.
10. BRIEFING--showing interviewers how to use the questionnaire.
11. INTERVIEWING--securing data from respondents.
12. CONTROLLING--seeing that the interviewing gets done.
13. VERIFYING--assuring that the collected data are accurate.
14. CODING--preparing the data for analysis.
15. PROCESSING--organizing data mechanically or electronically.
16. ANALYZING--interpreting the data.
17. REPORTING--sharing the new knowledge.

Source: Backstrom and Hursh (1976).

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[10] Thorough reviews of survey methodologies may be found in Bouchard (1976); Backstrom and Hursh (1975); Hansen, Hurwitz and Madow (1960); and Lansing and Morgan (1974). Costs cited are based upon selected research studies at Abt Associates in 1979-80.

Survey Type

The first and most important action in designing the survey procedure is the selection of approach from among personal interviews, guided interviews, telephone questionnaires and mail questionnaires. The selection of approach will influence the instrument design, as discussed above, and the cost of the effort and perhaps the resulting samples. The study of visibility aesthetics generally necessitates the more expensive personal interview or guided interview approaches. For personal interviews the field effort costs vary greatly, from $50 to $150 and up per interview, depending upon length, geographic location and whether or not individual respondents are preselected. The advantages of a personal interview are an increased amount of interaction and clarification between respondents and enumerators, less demands upon the format and presentation of the survey instrument and that respondents can be interviewed whenever a mutually acceptable time can be arranged.

Guided interviews of one or more respondents simultaneously often reduce costs by up to one half depending again on geographic location and the type of sample. Because many respondents usually must start the survey simultaneously, a random selection process of respondents--who may be forced to wait momentarily or come back at a later time--may be considerably hampered. For example, if only respondents with a strong interest choose to stay or return, the results will be potentially nonrandom and biased. The actions of some respondents in the process also may influence and bias other respondents through the transmittal of information clues which suggest appropriate answers.

The implementation costs of telephone surveys are on the order of one half or less of the costs of personal interviews. While random selection procedures can be easily applied, the response rates (self-selection to continue the questionnaire) is considerably diminished with lengthy telephone questionnaires. The rapport between respondent and enumerator is also often considerably reduced as is the ability to use any props to present alternative scenarios. This diminishes the effectiveness of surveys that are concerned with intended behavior based upon incremental changes in air quality: A verbal description of "a little more polluted" or "visual range of about 40 miles" is much less effective than the typical visual aids. This generally eliminates using telephone surveys for air quality demand studies. Telephone surveys are best used to gather perspectives, beliefs, and actual or intended behavior in well-defined and familiar situations.

The cost of mail questionnaires is typically one fourth or less of those of personal interviews unless elaborate materials are also required. Picture sets, for example, may drastically increase the cost of presenting alternative levels of air quality in mail questionnaires. Mail questionnaires are also notorious for having the lowest response rates and a greater need for validation. Mail questionnaires require very careful, simple formatting, and they quite obviously rule out the type of interaction that comes with the iterative bidding procedure. While they have been successfully used to evaluate wildlife stocks (Hammock and Brown 1974, and Brookshire et al. 1977), we are not aware of a validated attempt to use this approach to compare alternative scenarios of visibility aesthetics.

Sampling Procedures

Most survey research efforts face the problem of obtaining a random sample that is also a representative cross-section of the affected population. This may have been an especially important problem area for several previous bidding method surveys which have experienced high rates of unwillingness to participate by the initial randomly selected respondents (see Chapter 6). Responses cannot be obtained from all individuals who might be affected by a proposed project because both the cost of doing so and the volume of data generated would be overwhelming. Consequently, a sample of the population must be selected from which to infer characteristics of the population as a whole. Generally, a "probability sample" is designed where every individual has a known, although perhaps purposefully unequal, probability of being selected and where the resulting sample is a representative cross-section of the population. Such sampling must employ a predetermined yet completely random sample to insure the validity of the results and subsequent statistical analysis.

The probability sample must determine the number and kind of respondents, the probability any respondent would be included, the error involved from interviewing a sample rather than the whole population, and the degree of confidence in estimates made from the sample. One of three types of samples are usually designed and implemented. Where all individuals are considered to be alike (homogeneous) a simple random sample may be implemented. Where there are several different groups and where the individuals within a group are homogeneous, a stratified random sample, which attempts to insure that a minimum number of respondents within each group sampled, is performed. These approaches are aimed at sampling a particular random individual. Cluster samples are aimed at interviewing selected individuals from a randomly selected cluster of individuals, such as a household. A cluster sample simplifies efforts by determining the probability of being sampled and drawing actual samples for clusters of individuals, such as a household, rather than for all individuals in the population. Because household data are readily available and by randomly preselecting households and the members of households to be interviewed a random survey can be implemented with the cluster approach at a lower cost than for a simple random survey.

To implement a sample plan for urban locations, basic population characteristics are often needed, as are census tract information or local directories and a random selection procedure. For example, to interview members of selective households, information on the number and location of residences is required to calculate the probabilities of sampling any one household. A random selection procedure must next be implemented, such as selecting 100 sets of random blocks, households on the block and individuals within the household. The interviewer is then sent to the northeast (or other randomly selected corner) of the first block, turns right (or left) and interviews the selected individual in the first selected household. If the interview cannot be completed, a callback time is established. The interviewer then proceeds to the second selected block, etc.

Similar procedures must be implemented to obtain random samples at recreation areas. For example, obtaining a simple random sample with uniform probabilities of sampling an individual will depend upon how interviews are solicited. If interviews take place at camp sites, it is imperative to know the volume of use at each area. If interviews take place at park entrances, then more interviews will need to be conducted at high volume periods than at other times. As noted by Backstrom and Hursh (1976):

> In summary, the cardinal rule in sample drawing is to leave as much as possible to chance. When the researcher allows flip-of-the-coin philosophy to dictate his every move, he is assuring himself (and his critics) that whatever happens is completely devoid of his personal biases. In sampling, it is well to admit that almost anything you "decide" to do, rather than letting chance decide for you, is a contamination of the survey. (Page 64.)

Sample Size Determination and Verification

The necessary sample size is determined by a combination of inputs. These include the error limits and variances associated with the expected responses, the statistical tests for which the data are to be used and the expected completed response rate. These inputs are determined in part from the analysis planned and from the pretest of the survey instrument. Many previous visibility benefit surveys have employed samples of insufficient size for complete analysis.

A rule for every survey is that it must be pretested in the manner and location it will actually be applied. This identifies problem questions, error variance estimates, and response rates. The pretest sample size should be sufficient to determine these values and to test the robustness of the approach.

With estimated response rates and the calculated number of completed interviews required, the total number of interviews, the number of interviewers and the days in the field that will be required can be calculated in order to appropriately plan the actual survey effort.

A potential bias that has occurred in surveys concerning environmental issues is that of self-selection by the respondents. Many respondents, upon learning the intent of the survey effort, refuse to participate. If this participation rejection, or self-selection procedure, is non-random, so may be the results. For example, which individuals are more likely to allow enumerators to enter their homes, or are more likely to return and/or wait at a group interview site once the intent of the questionnaire is known?[11] Those most likely to have an interest, some who feel obliged, and a few with time on their hands? The possibility of higher response rates by those with a special interest may bias the sample if this effect is not tested and accounted for.

One way to test and adjust for self-selection bias is to identify two to three variables which are highly correlated with the values received in the pretest. For a study in Class I areas these might include residence location, environmental stance, recreation rates and income. Next, the rates at which these are found in the survey may be tested against the actual population totals. This can be accomplished in some cases with secondary data. On the other hand, if the sample differs from the general population by some important characteristics which cannot be determined with secondary data, such as environmental stance, the results of the survey may have a bias that is unknown and cannot be corrected. This may be a problem in bidding method surveys which often have experienced high rates of unwillingness to participate. It may be possible to offset this by a very low-cost 4-question random personal interview at a park entrance or through a city-wide telephone interview. An example at a park might read as follows:

> Hello, my name is ----- and I am with -----. We are doing a ----- park user survey which takes about one minute. Could you please answer the following question. (If no, attempt to establish a call back time.)
>
> Q1. In what city and state is your residence located?
>
> Q2. Have you recreated at this site in the past?
>
> Q3. How many days have you spent in national parks this past year?
>
> Q4. Using this card would you please tell me how you rank yourself on environmental issues? (some scales)
>
> Thank you very much.

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[11] A successful technique of increasing response rates at private residence, suggested by Mark Thayer and applied by Brookshire et al. (EPA 1981), is to introduce yourself and intent, then ask respondents to step outside their home to view a display on their front lawn. Respondents' homes will not be invaded, and with a sufficiently attractive display they are more easily enticed to cooperate in the survey.

If response rates to these or other appropriately selected questions are significantly different statistically from the sample response rates, the sample valuations should be appropriately adjusted and aggregated.

Post Survey Data Verification and Analysis

Once survey data are obtained, fairly standard statistical practices for validation, analysis, and reporting must be used. This section suggests several minimum efforts that should be made.[12]

First, all results should be reviewed and verified with interpretations and coding schemes checked before and after the coding and data entry tasks. Misinterpretation of results or errors in coding or data entry can easily invalidate many hours of well planned survey efforts. For example, unanswered WTP or WTA questions, which may frequently occur, will need missing value codes recognized by the statistical analysis routines. If these values are left blank and, in some programs, interpreted as zeros, all subsequent analyses will be invalidated.

In general, data analyses and presentation should follow and document standard statistical procedures in a consistent manner. Several types of analyses are almost always reported at least in working papers for any contingent market analysis. This should include tallys on the survey procedure, including the total number of respondents contacted, response or rejection rates for the whole questionnaire, and critical questions. Mean response rates to the bidding questions and their standard errors (standard errors of the means) and the number of observations upon which the means were calculated should be reported. Particularly useful data in bidding methods are mean bids, zero bids, and rejection bids for each scenario according to each stratification, such as by income classes, accompanied by the number of observations and the variances. Next, frequencies, correlations, and cross-tabulations of the bids, socioeconomic characteristics of the sample, and other variables of interest may be calculated. These will allow the researcher to check that the sample is representative of the population, to check for obvious data entry problems, and initially to evaluate the distribution of responses and correlations of variables.

Next, tests of specific hypotheses may be carried out, such as the effect of questionnaire design or socioeconomic influences upon the bids received. Because many different influences may be reflected in any particular bid it will be necessary to use multivariate analysis procedures such as regression analysis to separate out and test the influence of any one variable upon the bid structure. The depth of analysis that can be performed using regression analysis varies from ordinary least squares to simultaneous equation models with econometric tests of all underlying classical regression model assumptions. At a minimum, regression models explaining the bid distribution (bid functions) should be tied to models of consumer behavior and specifications of underlying utility functions. Because the "true" form of the respondents utility function and subsequent regression models is likely to be unknown, examining the robustness of the analysis by varying the functional forms is suggested. All regression results reported should at least include estimated coefficients, the number of observations, F statistics, t-statistics, and R^2's.

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[12] The reader may consult most any statistics or econometrics text for guidance, including Pindyck and Rubinfeld (1976), and Intriligator (1978).

Tests of a hypothesis should be careful to specify whether and why a test is two-tailed or one-tailed. Many past air quality studies have been flawed by the incorrect use of two-tailed statistical criteria when one-tailed tests were appropriate. For example, a null hypothesis may test that total willingness to pay for air quality is not affected by income. The alternative hypothesis suggested by economic theory is that total willingness to pay will increase with increases in air quality or income. Consequently, a one-tailed test would be appropriate.

4.3 Residential Property Value Studies

Residential property has been the market good most frequently studied to estimate the value of air quality from actual market data. The primary hypothesis behind this approach is that residential property values are influenced by the level of air quality at the residential site. Recently, similar approaches have been applied to recreational and commercial property and to other types of non-market amenities, such as noise and accessibility.[13] Residential property value studies are emphasized here because to date they are the most successful efforts of this type for estimating the benefits of air quality.

The use of residential property value differentials to estimate how much consumers are willing to pay for various levels of air quality began with the Ridker and Henning (1967) study in St. Louis. It was based on the supposition that if air quality varies across the area and if people are willing to pay more for a residence with better air quality, the amount they are willing to pay will be revealed by the price differences between properties that are similar in all respects except air quality. None of these types of studies have attempted to separate health effects from aesthetic effects of air quality. Therefore the discussion in this section refers primarily to air quality, although the potential for isolating visibility aesthetics will be discussed.

The variations and refinements of the Ridker and Henning approach that have been developed since 1967 are based largely on the hedonic price technique. The following section introduces this technique and explains the procedure in a non-technical manner. However, functional notation and graphical presentations are necessary to explain this technique and its strengths and weaknesses. The more technical application details are presented in Section 4.3.2. Anyone interested in applying this technique or in acquiring a thorough understanding of its application details will need to master this material. Two variations of the property value studies that have been used are the residential location model and the matched pairs technique. These are briefly described in Section 4.3.3. The strengths and weaknesses of the property value approaches are presented in Section 4.3.4.

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[13] For examples see Wilman 1981; and Palmquist 1981.

4.3.1 Introduction to the Hedonic Price Technique

Economists usually look at the prices paid for goods and the quantities purchased to determine how much people value a market good. With this information a demand curve can be estimated from which the benefit measures defined in Chapter 2 are derived. With non-market goods, such as visibility aesthetics, there are no direct prices and quantities, but in some cases the selection and price paid for a market good, such as a residential property, may be influenced by visibility levels. In this way, analysis of air quality levels and residential property prices may reveal the value that people place on visibility aesthetics. The hedonic price technique can be used to estimate the implicit price for a non-market good that is associated with and influences the value of a market good.

Conventional consumer behavior theory postulates that consumers derive utility directly from goods and services that are each obtained in homogeneous (identical) units. However, many goods are not purchased in homogeneous units. For example, different houses have different numbers of rooms, distances from employment centers, yards, and views. The hedonic price technique, as developed by Griliches (1971) and Rosen (1974), attempts to analyze the value of such goods by breaking them down into the attributes that they embody. Hedonic price theory suggests that consumers select the particular bundle of attributes that they desire when purchasing a differentiated market good, such as housing, and that it is from these attributes that consumers derive utility. In other words, the household values a residential property because it embodies particular attributes that the household desires, such as places to sleep and eat, a pleasant environment, and access to employment and recreation. This approach is related to Lancaster's (1966) modification of consumer behavior theory, which is that consumption is an activity into which goods and services are inputs and from which attributes or characteristics are derived. The hedonic approach, however, does not suggest that households produce these attributes themselves, as does Lancaster, but that they select from among the bundles of attributes contained within available market goods such as housing.

The amounts of the attributes in a market good determine the prices that consumers are willing to pay for the market good. If these attributes can be defined and quantified by a consistent unit of measure, then by observing different units of a market good with different levels of attributes, such as houses with different amounts of rooms, and air quality, the effect of each attribute on the price of the market good can be determined. This relationship between the price of a market good and its attributes is called a hedonic or implicit price function and its estimation is the first step of the hedonic price technique. The hedonic price function enables the analyst to statistically hold all attributes but one constant and to see how the level of one attribute affects the price of property. It can answer the question of how differences in visibility would affect prices of property if each residence were identical in every other respect.

From this hedonic price function a marginal implicit price for each attribute can be derived. The marginal implicit price of an attribute is the addition to the price of the good that must be paid to obtain a good with an additional unit of the attribute. If one of these attributes is a measure of visibility, deriving a marginal implicit price for visibility from a hedonic price function would be a first step toward estimating the willingness to pay for visibility. The next step requires observation of how marginal implicit prices for visibility change when visibility levels change either across locations or across time.

The most recently published property value studies that have estimated the value of air quality as an attribute of residential property have been based on the theoretical framework developed by Rosen (1974) and Freeman (1974). The Rosen and Freeman analysis cleared up some of the problems and confusions in interpretation of property value differentials in the earlier studies primarily by pointing out that observed differences in property values attributable to differences in air quality can only be interpreted as willingness to pay for that difference in air quality under special and typically unrealistic conditions. However, the procedure that they both suggested for estimating WTP from a hedonic price function has been a subject of recent debate. Suggested modifications to this approach have not yet appeared in published theoretical or empirical work and are still in formative stages. Therefore the unmodified Freeman and Rosen framework is presented here with its current shortcomings. The reader should be aware that recommended changes in the WTP portion of this approach are likely to be forthcoming.

The following simplified example illustrates a hedonic price function for residential property. A few attributes of a residential property a household may value include:

A1 = size of house
A2 = distance from work site
A3 = size of yard
A4 = neighborhood crime rate
A5 = quality of neighborhood schools
A6 = air quality at house site

For purposes of this illustration assume that these six attributes are those that are important to households when selecting a residence and that these attributes are observable and quantifiable. A list of all relevant residential property attributes would, of course, be much longer. A linear form of the hedonic price function for residential property would be:

$$PV = b0 + b1A1 + b2A2 + b3A3 + b4A4 + b5A5 + b6A6$$

where:

PV = residential property value
b0 = a constant
b1,...,b6 = coefficients of each corresponding attribute

The analyst obtains data for the prices and attributes of the good and uses regression analysis to estimate the coefficients of the function. Residential property value, presumably the sale price it could obtain, is given here as the price of the housing good. This choice and other possibilities are discussed in detail in Section 4.3.2.

From this hedonic price function a marginal implicit price can be derived for the air quality at the residence. In this case the estimated value for b6 would be the marginal implicit price for air quality. It indicates how much additional money the household must pay for each incremental improvement in air quality at the residence. The household cannot buy improvements in air quality at a given site, but it can choose among residences that are similar in all respects except the level of air quality. A linear hedonic price function implies that the marginal implicit price of air quality is a constant.

A linear form for the hedonic price function, however, will probably not be appropriate because it is impossible to repackage housing bundles without additional cost. For example, a linear hedonic price function implies that the value of two 750-square-foot homes is equivalent to the value of one 1,500-square-foot home. Though the amount of materials in each may be the same, converting the two houses into one or the one into two would be a difficult and expensive undertaking. A nonlinear hedonic price function implies that the marginal implicit price of air quality and other attributes is not constant.

The general form for the hedonic price function for property value, PV, is:

$$PV = PV(A_i, \ldots, A_n)$$

where:

A_i = the quantity of the ith attribute of the property

The marginal implicit price of attribute Ai is the partial derivative of the hedonic price function with respect to attribute Ai, $\partial PV/\partial A_i$. This derivative will be a function of Ai and possibly other attributes unless the hedonic price function is linear. For example, an increase in air quality where the air quality is poor might obtain a higher marginal implicit price than an increase in air quality where air quality is good. Also, a house with large windows might obtain a higher marginal implicit price for air quality than a house with small windows.

Examples of a nonlinear hedonic price function and a marginal implicit price function for air quality are given in Figure 4.1. PV(Q) is the relationship between property values and air quality taken from a hedonic price function for property holding all attributes but air quality constant. The marginal implicit price function for air quality, which is designated as PV'(Q), is the partial derivative of the hedonic price function with respect to air quality, $\partial PV(Q)/\partial Q$. PV'(Q) is thus the slope of PV(Q). For many nonlinear forms of the hedonic price function, the marginal implicit price of air quality will be a function of other property attributes as well as of air quality. PV'(Q) in Figure 4.1b is therefore the relationship between the marginal implicit price of air quality and the level of air quality holding all attributes but air quality constant.

The goal of the analysis is to estimate the value of air quality so that the benefits of an improvement or the damages of a deterioration in air quality can be evaluated. Identifying a marginal implicit price function for air quality is, in most cases, just a first step. The second step in the hedonic approach is to estimate the demand function for air quality at the residence. This is the relationship between the marginal implicit price of air quality and the level of air quality at which the household will choose to locate. It must also account for the effects of household income, household size, and other household characteristics and property attributes that influence the household's demand for air quality.

This demand function is usually called the WTP function because air quality is a public good and the household is limited in its choice of how much air quality to consume. For a market good the demand curve tells how much the consumer will buy at a given price. The WTP curve tells how much the consumer would be willing to pay for each increment of air quality. They contain the same information, but in one the dependent variable is quantity and in the other it is price. The marginal implicit price function for air quality is a relationship between the price and the level of air quality, but it is not normally the same as the WTP function because it is the result of supply and demand interaction. The prices are established where the supply of residential site air quality equals the demand for residential site air quality at each air quality level.

The marginal implicit price for air quality that each household is paying may be considered one point on its WTP curve. Two possible willingness to pay curves are shown in Figure 4.1b. These are Wi(Q) for household i and Wj(Q) for household j. Like normal demand curves they are downward sloping and they intersect the marginal implicit price function at the marginal implicit price and air quality combination at which the utility maximizing household will locate. Because each individual household will typically have an inconsequential influence on the demand and supply of residential property, it will face the market determined marginal implicit prices for all property attributes. A household will maximize its utility by choosing a property with levels of each attribute where its marginal willingness to pay for each additional unit of the attribute just equals the marginal implicit price. Hence, household i chooses a residence with air quality level Qi and household j chooses a residence with air quality level Qj.

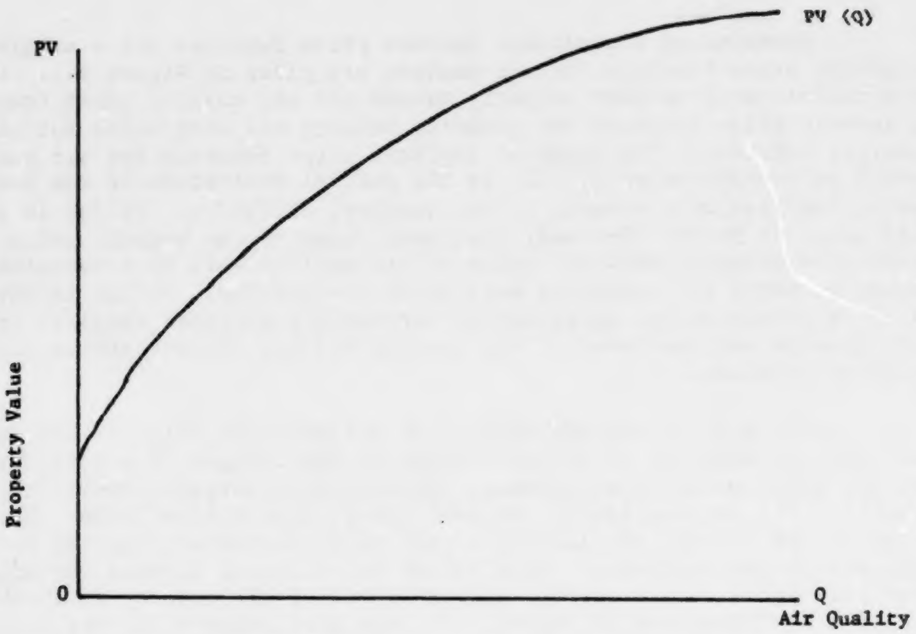

Figure 4.1a

Hedonic Price Function for Air Quality

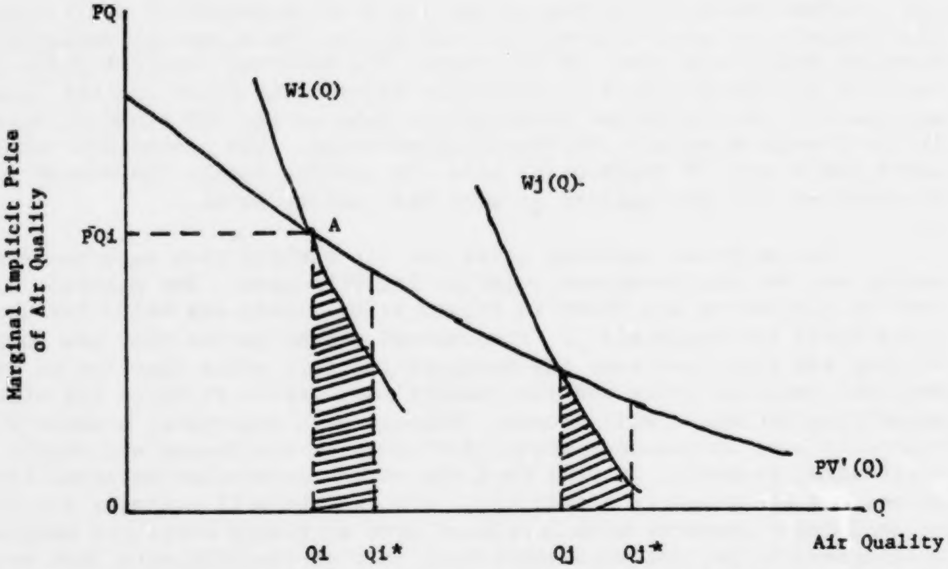

Figure 4.1b

Marginal Implicit Price Function and Willingness To Pay Functions For Air Quality

PQi can be considered household i's marginal willingness to pay for the ith unit of air quality and as such represents the household's willingness to pay for a marginal (very small) change in air quality. However, public policy questions typically require estimation of the household's willingness to pay for non-marginal changes in air quality, for which the WTP curve must be known.

The WTP functions for air quality are estimated by deriving the marginal implicit price from the hedonic price function that each household is paying and taking this as a measure of its willingness to pay for the air quality level at its residence. By using household income and other household characteristics to group together households that are similar, a set of willingness to pay functions can be estimated. The estimated willingness to pay function is therefore:

$$PQi = Wi\ (Qi,\ Mi,\ Zi1,\ldots,Zin,\ Si1,\ldots,Sim)$$

where:

PQi = the marginal implicit price for air quality being paid by household i

Mi = the ith household's income

Zi1,...,Zin = other characteristics of household i

Si1,...,Sim = other attributes of household i's residence

However, because the implicit price function is also influenced by supply side variables, estimation of WTP requires consideration of the supply of residential site air quality as well. This will be discussed in Section 4.3.2.

Consumer surplus measures can be derived from the WTP curves. In this case, because the individual is able to vary his consumption bundles but appears to have no property rights to any level of air quality, other than what he purchases in the market, the compensating variation measure is appropriate. However, since the error in the WTP estimation will be likely to greatly exceed the error in approximation when using ordinary consumer surplus, the OCS measure is typically used. As was shown in Chapter 2 this is an approximation of the change in welfare, or equivalently, an approximation of how much households value the change. This is illustrated in Figure 4.1b. Household i lives at a location with air quality Qi and household j lives at a location with air quality Qj. Each household's willingness to pay for an improvement in air quality from Q to Q* at its locations is shown by the slashed area under each household's willingness to pay curve. This is the integral of the WTP function between the original and the improved air quality levels. It represents an OCS measure of the benefits to each household of the improvement in air quality, because it indicates how much the household would be willing to pay for the air quality improvement in excess of the expenditures it is currently incurring.

The application of the hedonic price technique requires several assumptions. The first of these is that households are sufficiently mobile and aware of air quality impacts to cause current property values to reflect the marginal willingness to pay for the current air quality conditions. This will ensure that PQi in Figure 4.1b is a point on household i's marginal WTP curve. For this to occur households must have enough information about air quality in a neighborhood in which they buy or own a residence that they can make a reasonable judgment about what the impact of living in such conditions would be, and there must be enough competition among buyers that prices reflect the marginal value of the properties to the households that purchase them. When actual sales data are used in the hedonic price study this assumption will be valid as long as households choose optimal (utility maximizing) residences when they move, but transactions costs may keep households from moving when changing conditions have rendered their current residences non-optimal for them. Even if owner or appraiser estimated property values reflect current market conditions it may not be valid to assume that the current market value reflects the occupant's marginal willingness to pay for a property that has not been recently purchased. Freeman (1979b) argues that making this assumption will introduce error but not necessarily bias unless market conditions have been changing consistently in one direction and households have been lagging behind in their adjustments to the changes.

The second assumption is that there is continuous variation in each attribute, Ai, and that all combinations are available so that consumers can increase their consumption of Ai by finding another residence that is identical in all other attributes but embodies more Ai. The observed price will not be equivalent to marginal WTP if the combination of attributes that would maximize the household's utility given current prices is not available. Freeman (1979b) points out that violation of this assumption may be why Harrison and Rubinfeld (1978) found that some high-income households chose to live in high-pollution areas even though they had a higher willingness to pay for air quality. He suggests that this may be because they wanted a combination of low pollution and high levels of some other attribute, such as proximity to the cultural amenities of a downtown area, that was not available.

The third assumption is that all relevant attributes must be observable and quantifiable. The transition from a model that maintains that a good embodies attributes which are valued to the empirical realization of it that permits the estimation of marginal implicit prices for these attributes is quite difficult. The application of the hedonic price technique assumes that the price households are willing to pay for a residence can be fully explained by specific measures, such as the number of rooms, the distance from a shopping center, the amount of crime in the neighborhood, and the amount of air pollution in the neighborhood. This requires that, for example, a technical measure of air pollution levels be used to sort out which of the household's decisions and actions are attributable to air quality conditions. This presumes that the technical measure is a reasonably accurate reflection of the household's perceptions of air quality. If all relevant attributes are not accurately specified, variations in property value that actually result from differences in attributes that have been overlooked or incorrectly measured may be inaccurately attributed to the attributes that have been used.

4.3.2 Application

Applying the hedonic price technique to residential property is a complicated task because data must be put to a use for which they were not originally collected and because air quality is only one small part of all the factors that determine residential property values. This section presents some of the more important theoretical and practical details that must be considered.

The Hedonic Price Function: Dependent Variable

The dependent variable of the hedonic price function is the price per unit of the market good, in this case residential property, that is being examined. It is not entirely clear what price should be used in a property value study. Freeman (1979a) argues that the value of land would be the best price to use when trying to isolate an implicit price for air quality because the complications caused by variations in the housing structure could then be avoided. However, land and the structure on it are usually sold as a unit for a price that reflects their combined value, hence information on property values is more readily obtained.

It is theoretically possible to use either or both cross-sectional or time series data because air quality can vary across locations and across time. However, most studies have used only cross-sectional data or cross-sectional data over a short time period, such as a year or two. There are two primary reasons for this choice. One is that changes in property values over time are probably more complex and therefore more difficult to explain than differences across locations. The second is that a major data source for many of the studies has been the U.S. Census of Population and Housing, which is conducted every ten years and is therefore not a suitable source for time series data especially because air quality has only begun to be monitored during the past ten to fifteen years in most major urban areas.

The appropriate measure of property value for a hedonic price function is the price that the property would obtain if sold during the study period. However, only a fraction of residential properties are sold during any given time period. The analyst must therefore choose whether to use the subset of the properties that are actually sold during the study period or whether to use estimates of the market value of all the properties in the study area. Data on property sales including price and property characteristics are available from local government, market research firms, real estate organizations, or financial institutions. Estimates of the market value of properties that have not been recently sold can be obtained by professional appraisal of all individual properties in the study area or from county records kept for tax purposes. The latter source should be used with caution, however, because political motives and infrequent reappraisal may lead to inaccurate records of property value. Census tract averages of the owner-estimated value of the properties reported by the U.S. Census of Population and Housing are frequently used because they are readily available, but some information is lost in averaging the data within a census tract and the census data do not cover all the variables that might be desired for estimating a hedonic price function for residential property. The San Francisco Bay Area study (Loehman et al. 1980) tested for the effects of different levels of aggregation and found that though results are influenced by the level of aggregation, household level analysis may not be necessary.

The above discussion refers to owner-occupied housing, but a significant fraction of housing is rented. The observable price in the rental market is the annual or monthly rent. Some studies have estimated separate hedonic price functions for these two markets though most have looked only at owner-occupied housing. However, the relationship between property values and rents can be used to convert either one to the other so as to combine rental and owner-occupied housing prices if the researcher chooses to put them into one hedonic price function. Though most studies have used only owner-occupied housing prices the same sort of conversion must be made to translate benefit estimates based on property values to annual benefit figures.

A residence is a long-term asset from which the occupant receives benefits over many year; therefore, the price that a household is willing to pay to purchase a house is the present value of this expected future stream of benefits. Similarly, the annual rent that the household is willing to pay is equal to the annual benefit expected from occupying the house. To obtain a present value, future benefits are discounted because a benefit received next year is worth less than the same benefit received this year due to the intervening time. For example, consider a household that is buying a property for which it would be willing to pay an annual rent of $5,000. Suppose also that the interest rate it could get by putting its money in the bank instead by buying a house is 10 percent. The present value, in this case the value of the property to the household, of a perpetual stream of $5,000 in benefits annually when the discount rate is 10 percent is:

$$\frac{\$5,000}{.10} = \$50,000$$

In general, where :

r = annual rent (benefit)

R = property value (present value)

i = the discount rate

the approximate relationship between annual rent and property value is:

$$r = Ri.$$

This formula assumes that the annual benefits will continue indefinitely and unchanged whereas in reality the household's time horizon is finite and benefits will be offset by increasing upkeep costs as the house ages. More complex discounting formulas can be used if a more accurate approximation is required (see Chiang 1974).

Similarly, a benefit estimate for changes in air quality based on property values will be the present value of the stream of expected future benefits of the change in air quality. It can be converted to an annual benefit figure in the same way that property values can be converted to annual rents, but some assumptions must be made about whether households expect current air quality conditions to remain unchanged when they purchase a residence and about how long the new air quality condition will exist.

The Hedonic Price Function: Independent Variables

The independent variables of the hedonic price function are the attributes of the market good being examined. Not only must the appropriate price data for property be chosen, but all the appropriate data to describe all the relevant property attributes must also be selected.

To estimate the hedonic price function for residential property, the independent variables must include all the attributes that influence the value of the property.[14] The choice of these attributes has in practice been very dependent on data availability and has varied significantly from one study to the next. These attributes can be separated into two categories: house structural variables and neighborhood characteristics and amenities. Table 4.5 gives some examples of variables that have been found to influence property values in studies that have estimated willingness to pay for air quality from property values.

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[14] This difficulty may eventually be avoided in some cases with the use of the repeat-sale technique described by Palmquist (1981). This new approach observes changes in sale prices of homes before and after an environmental change has occurred. Because the same homes are being observed over time the characteristics other than environmental quality are unchanged and therefore do not need to be considered.

Table 4.5: Property Attributes Found Significant in Air Quality Studies

House Structure	Neighborhood Characteristics
Age of House	Property tax
Number of Rooms	Percent Non-white
Lot Size	Population/Square Mile
Number of Bathrooms	Crime Rate
Air Conditioning	Percent Business Acreage
Sales Date	School Quality
Pool	City Services
Fireplace	Accessibility to Transportation Facilities
Persons per Room	Distance to Central Business District
Square Footage	Noise
	Proximity to Recreation Facilities
	Proximity to Employment
	Air Pollution

Source: Loehman et al. (1980) p. 80

The differences between studies in property attributes used in the hedonic price function may not be as problematic as they first appear, because many of the attributes are correlated with one another. For example, the number of square feet and the number of bathrooms in the house may be slightly different measures of the capacity of the house. The analyst must be careful, however, to identify all the attributes that influence property values, because the influence of omitted attributes will be statistically attributed to the attributes included in the hedonic price function if they are correlated.

If the analyst is only concerned with separating the effect of air quality from the other attributes, incorrectly attributing the influence of the number of bathrooms to the number of square feet in the house will not be a problem; however, if omitted attributes are correlated with air quality, the impact of air pollution on property value will be either over or understated. For example, air pollution typically decreases as the distance from the central business district (CBD) increases. If the distance from the CBD is omitted from the hedonic price function, the negative influence of air pollution on property values will be understated, because proximity to the CBD (easier access to theaters, stores, employment) can be expected to exercise a positive influence on property values. The benefit of being close to the CBD will counterbalance the damage of the increased air pollution close to the CBD, and the negative influence of increased air pollution on property values will appear to be smaller than it actually is. Alternatively, air pollution may be positively correlated with traffic noise. If traffic noise is omitted, the pollution will pick up the negative influence of traffic noise as well and be overstated.

Until now air quality has been discussed as if it were a unique, measurable attribute of a property or neighborhood, but in fact the most available measures of air quality are the levels of monitored air pollutants. In most urban areas these include carbon monoxide, total suspended particulates, oxides of nitrogen, oxides of sulfur, and ozone, as well as some composite measures such as the Pollution Standards Index. The analyst must choose the pollution measure or measures that best reflect the air pollution impacts that influence property values, taking into account the availability and quality of the pollution data.

A serious problem for the accurate interpretation of the effect of the selected pollution measure on property values is that many of these measures are highly correlated with one another. This makes it difficult to separate the property value impact of one pollutant from the impacts of the other pollutants, even though each pollutant tends to have a different kind of impact on people and property. In a situation where different pollution measures are highly correlated, one measure must be selected as a proxy. The estimated marginal implicit price for the selected pollution measure will then to some extent reflect the impacts of all the correlated pollution measures. There is no way to entirely correct this problem, and the analyst must check for its seriousness and take this into account in interpreting the results of the hedonic study.

Most of the studies have chosen one measure of pollution as a proxy for air quality and have not attempted the difficult task of separating health effects from aesthetic effects. If the hedonic price technique is to be used to measure the value of visibility, a measure of visibility must be developed that is distinct from the other impacts of air pollution. Measures of visibility are discussed at length in Chapter 3. Though visibility alone has not been used in a hedonic price study, some pollutants used have more visibility impacts than others and visual impacts may very well be those most readily perceived and therefore reflected in property values. The difficulty would be in trying to separate the visual from the health and other impacts. If a single pollutant causes more than one type of impact it may not be possible to statistically separate their effects on property values.

Available pollution data are limited because the number of monitoring stations in an area is limited and may not correspond to the property locations being studied. Some of the recent studies (Harrison and Rubinfeld 1978; and Bresnock 1980) have used air dispersion models that produce estimates of air pollution levels over a grid of the area using monitor station and wind pattern data. These models increase the flexibility of the property values study, but the accuracy of the study then depends on the accuracy of the dispersion model.

The Hedonic Price Function: Functional Form

To estimate a hedonic price function, a specific functional form must be selected.[15] An example of a linear hedonic price function was given in Section 4.3.1, and several of the earlier studies used this form. However, the hedonic price function does not have to be linear since it is not possible to repackage housing bundles without additional cost. Additionally, without any variation in marginal implicit price over the study area one cannot observe households' responses to different prices of air quality and therefore cannot estimate a willingness to pay curve for air quality. Fortunately, both a priori considerations and empirical evidence support the assertion that nonlinear functional forms give a superior hedonic price function to linear functional forms.

An important consideration in the selection of the functional form for the hedonic price function is the nature of the relationship between property values and the air quality or pollution measure being used. Air pollution is an attribute of residential property that has negative utility for households and therefore has a negative price. Air quality would have a positive price. It may sometimes be possible to use positive measures of air quality, such as visual range, but because measures of air pollution are more readily available and have been used in most of the property value studies they will be emphasized here. Beyond the expectation that as air pollution increases property values will fall, the shape of this relationship is not known and is not predicted by consumer demand theory. The appropriate functional form for this relationship must therefore be determined empirically. Transformations of the pollution data, such as using the reciprocal in order to obtain a measure of air quality, impose specific functional forms on the pollution and property values relationship. Therefore, such transformations should not be used arbitrarily and, if determined to be appropriate, should be used consistently throughout the analysis.

Figure 4.2 shows a possible relationship between air pollution and property values. The upper quadrant shows that as pollution increases property values fall at an increasing rate. Therefore the first derivative is negative and downward sloping. This is the marginal implicit price function for air pollution shown in the lower quadrant. It implies that the amount a household will be compensated for each additional unit of air pollution increases as air pollution increases. Other hedonic price functions for property value as a function of air pollution might imply an upward sloping marginal implicit price function. However, all such hedonic price functions can be expected to be downward sloping and therefore all the marginal implicit price functions for air pollution will be in the negative quadrant. WTP functions for a negative attribute, such

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[15] More detailed descriptions of functional forms specifically with regard to hedonic price functions can be found in Freeman (1979a). General discussions regarding applied econometrics can be found in Pindyck and Rubinfeld (1976).

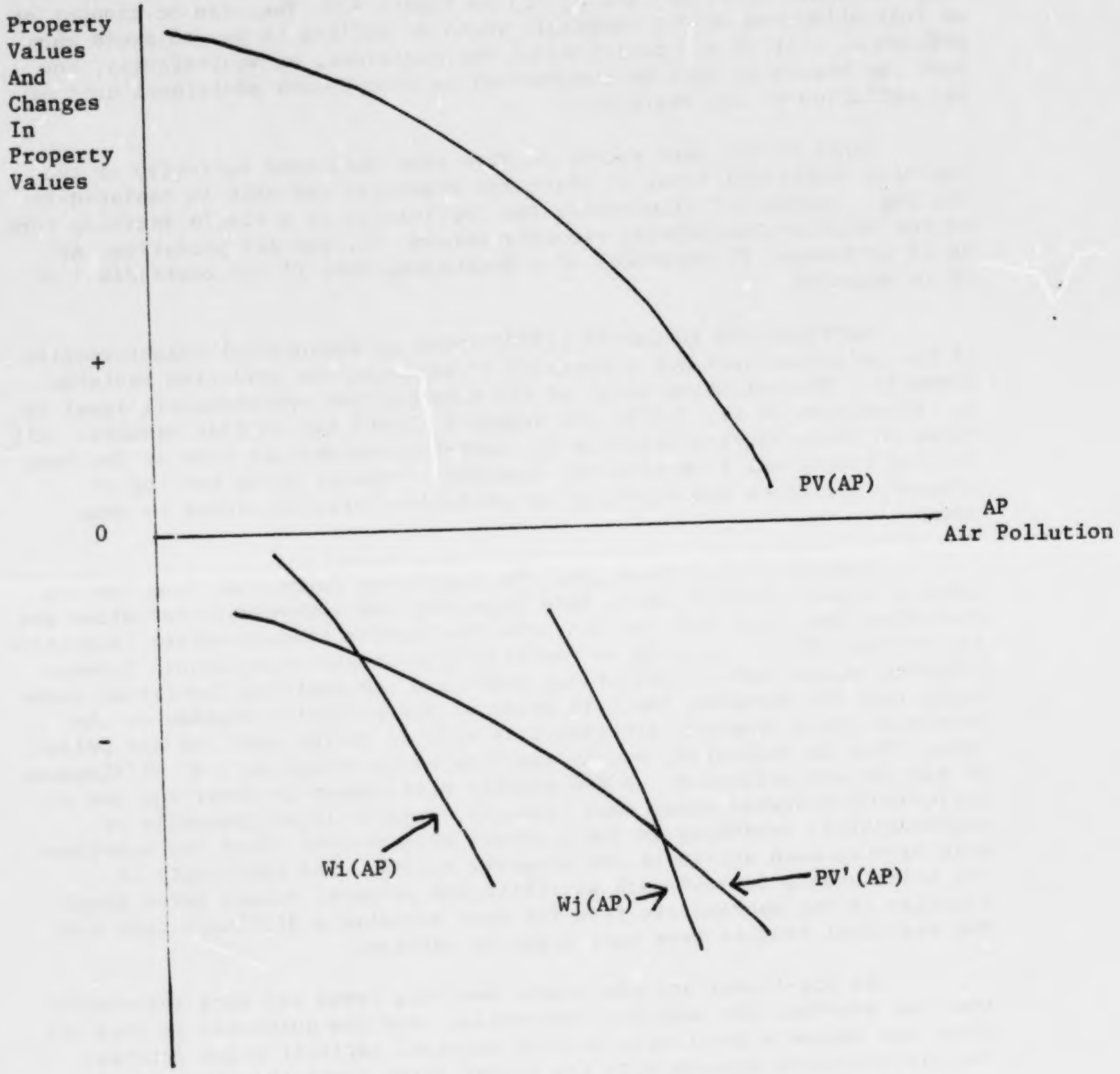

Figure 4.2

An Example Of The Relationship Between Property Values and Air Pollution as air pollution, can be expected to be downward sloping in the negative range as shown by Wi(AP) and Wj(AP) in Figure 4.2 They can be thought of as indicating how much a household would be willing to pay to avoid each additional unit of air pollution at the residence, or equivalently, how much the household must be compensated to accept each additional unit of air pollution at the residence.

Most of the more recent studies have used some variation of the semi-log functional form, in which the dependent variable is replaced by its log. Figure 4.3 illustrates the implication of a simple semi-log form on the relationship between property values, PV, and air pollution, AP. As AP increases, PV decreases at a decreasing rate if the coefficient of AP is negative.

Harrison and Rubinfeld (1978) found an exponential transformation of the pollution variable preferable to entering the pollution variable linearly. The estimated value of the exponent was approximately equal to 2. Brookshire et al. (1979) and Bresnock (1980) had similar results. All three of these studies selected the semi-log exponential form as the best fitting functional form with the dependent variable being the log of property variables and entering the pollution variable raised to some power.

Several studies have used the log-linear functional form for the hedonic price function, where both dependent and independent variables are converted into logs, and one has used the Box-Cox transformation (Sonstelie and Portney 1977). As well as implying a nonlinear relationship between property values and air pollution, these and the semi-log functional forms imply that the marginal implicit price of air pollution depends on the levels of other property attributes as well as on the level of air pollution. This is realistic, but it complicates the estimation of willingness to pay for air pollution. A few studies have chosen to enter the non air pollution attributes other than linearly, usually logarithmically or exponentially, depending on the a priori expectations about the relationship between each attribute and property values. The complexity of the relationship between each attribute and property values makes specification of the appropriate form for each variable a difficult task that the empirical studies have only begun to address.

The log-linear and the simple semi-log forms are more restrictive than the Box-Cox, the semi-log exponential, and the quadratic in that the first two impose a positively sloping marginal implicit price function for air pollution whereas with the latter three forms the slope of the marginal implicit price function is unrestricted. There is not necessarily any a priori reason to expect either a positively or negatively sloping marginal implicit price function for air quality because it is the result of the interaction of both demand and supply. Therefore, a functional form that does not restrict the slope of the marginal implicit price function is preferable. Whether this slope will be positive or negative is determined by the sign of the second derivative of the hedonic price

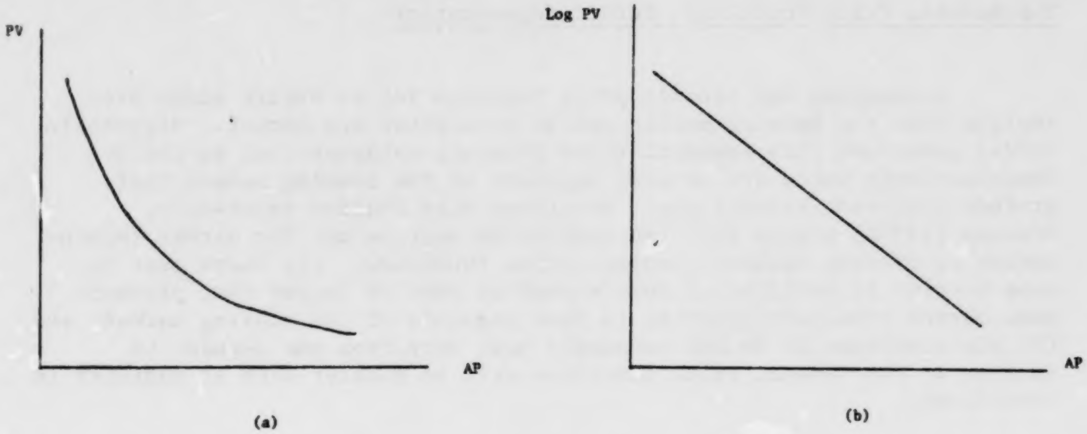

Figure 4.3

A Semi-Log Functional Form

function with respect to air pollution.[16] A negatively sloped marginal implicit price function as shown in Figure 4.2 indicates that as air pollution increases property values decrease at an increasing rate. This implies that households must pay more to move from high levels of air pollution to moderate levels than to move from moderate levels of air pollution to low levels, other things such as house quality being equal.

Studies that have experimented with different functional forms have found that coefficients in the hedonic price function are quite sensitive to changes in functional form. This means that the functional form chosen for the hedonic price function will influence the benefit estimates. Uncertainty as to the appropriate form therefore adds risk to the use of this technique. Evidence from the empirical studies about the appropriate functional form for the hedonic price function is discussed in Chapter 6 and is not, at this time, particularly conclusive. This suggests that the researcher should examine several alternative functional forms and test the sensitivity of the final benefit estimates to changes in the form of the hedonic price function.

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[16] Freeman (1979a) derives the second derivative for each of the commonly used functional forms and, assuming that the coefficient of the air pollution variable is negative, he predicts under what conditions the second derivative will be positive or negative. However, there are a few errors in the table. The second derivative of the semi-log form should be b^2R and the second derivative given for the semi-log exponential form is correct only if $c = 2$. For all c, it should read P^{c-2} cbR $[(c-1) + cbP^c)]$ and it will be negative if $cbP^c > -(c-1)$ as long as $c > 0$. When $c = 2$, the second derivative will be negative if $2bP^2 > -1$.

The Hedonic Price Function: Market Segmentation

Estimating one hedonic price function for an entire study area implies that the housing market can be considered one market. Straszheim (1974) questions this assumption and presents evidence that in the San Francisco area there are several segments of the housing market that produce different hedonic price functions when studied separately. Freeman (1979a) argues that two conditions must be met for market segmentation to produce separate hedonic price functions: (1) There must be some barrier to mobility of buyers such as race or income that prevents some buyers from participating in some segments of the housing market; and (2) the structure of demand or supply must vary from one segment to another or the hedonic price functions will be similar even if mobility is restricted.

If market segmentation does exist, separate hedonic price functions must be estimated for each segment. Empirical evidence tentatively suggests the existence of market segmentation. Harrison and Rubinfeld (1978) separated the Boston housing market into low, medium, and high household income submarkets and found that the hedonic prices for air quality varied from one submarket to another. Bresnock (1980) separated the Denver housing market into two submarkets--low-income non-white and high-income white--and also found significantly different hedonic prices in the two submarkets. Loehman et al. (1980) used a different criteria and separated the San Francisco Bay Area into two geographical submarkets, East Bay and West Bay. These were selected as distinct submarkets because over 80 percent of the working residents of the West Bay area were employed in the West Bay area and over 80 percent of the working residents of the East Bay area were employed in the East Bay area. They also found different hedonic prices in each submarket. On the other hand, Nelson (1978) found no evidence of market segmentation between urban and suburban areas in Washington D.C.

Ignoring market segmentation, if it in fact exists, will distort the estimation of benefits of an improvement in air quality. Whether true benefits would be overstated or understated depends on the distribution of the air quality improvement and on the WTP in each market segment. It is not clear, however, exactly how the housing market should be segmented. Uncertainty as to the appropriate functional form for the hedonic price function makes it difficult to confidently test for market segmentation because hedonic prices could appear to change from one submarket to another submarket in the study area due to an incorrectly specified functional form as well as due to actual market segmentation. Segmentation according to income and/or race appears to be successful, and separation into self-contained residential and employment areas seems to make sense, but more evidence is needed to support the conclusion that the housing market is actually segmented along any of these lines. Bresnock (1980) suggests that information about actual housing transactions and real estate market information linkages could improve the current methods for segmenting the housing market.

Estimation of Willingness to Pay

The empirical relationship between the hedonic price function and the willingness to pay for a particular attribute is probably the most problematic link in the work that has used the hedonic price technique to estimate the benefits of a change in air pollution. Therefore it is important that anyone who is interested in doing a hedonic price study or in critically reading studies done by others understand this relationship and its theoretical development.

Figure 4.4 is taken from Rosen (1974). This article and Freeman (1974) developed the theoretical relationship between the hedonic price function and WTP upon which most of the empirical work has since been based. This presentation will use air quality rather than air pollution because the reasoning is applicable in either case and working with a negative attribute adds an unnecessary complication. The relationship between property values and the property's air quality attribute is PV(Q), which is taken from the hedonic price function for property values holding all attributes except air quality constant. These observed combinations of property values and residential site air quality levels are determined by the equilibrium tangencies between the household bid curves and the supplier offer functions.

The household bid curve shows the prices the household would be willing to pay for a residence with different levels of air quality. Therefore the household's utility is held constant along the bid curve and the household is indifferent between the property price and air quality combinations traced out by the curve. The position of the bid curve that represents the highest utility obtainable by any particular household is determined by household income and tastes and other demand determining factors. In Figure 4.4a two such bid curves are drawn. Because the PV(Q) function shows what any household must pay to obtain a residence with each corresponding level of air quality, household i will locate at point A where the household i bid curve is tangent to the hedonic price function. The bid curve represents the highest utility that household i can obtain and PVi and Qi is the only combination on that bid curve that household i can obtain in the housing market. Any other point on PV(Q) would represent a lower level of utility for household i, hence it is in equilibrium at point A. Similarly, household j locates at point B. It is located at a higher level of air quality because of having a higher income or stronger preferences for clean air (possibly someone in the household has poor health that is aggravated by air pollution).

The supplier offer curve shows the price the supplier would be willing to accept for supplying a residence with different levels of air quality. Profits are constant along the offer curve so that the supplier is indifferent between locations along it. As with the household, the supplier can only obtain a price that is on the PV(Q) curve. He will be in equilibrium when supplying the amount of residential site air quality

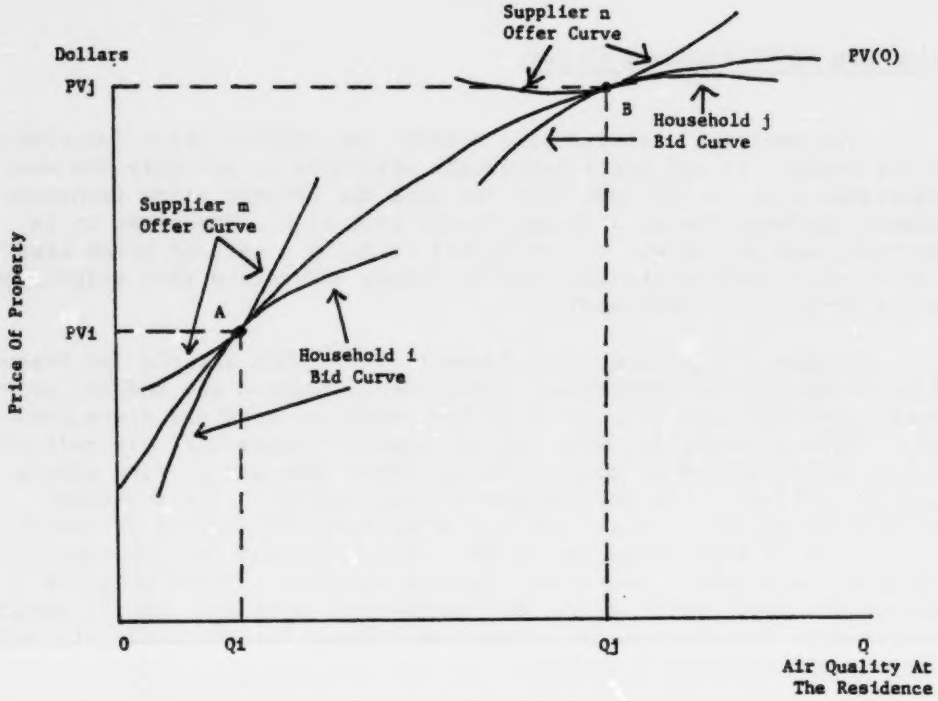
Supplier n
Offer Curve
Dollars
PV(Q)
PVj
B
Household j
Bid Curve
Supplier m
Offer Curve
Price Of Property
A
PVi
Household i
Bid Curve
0
Qi
Qj
Q
Air Quality At
The Residence

Figure 4.4a

The Hedonic Price Function for Residential Property

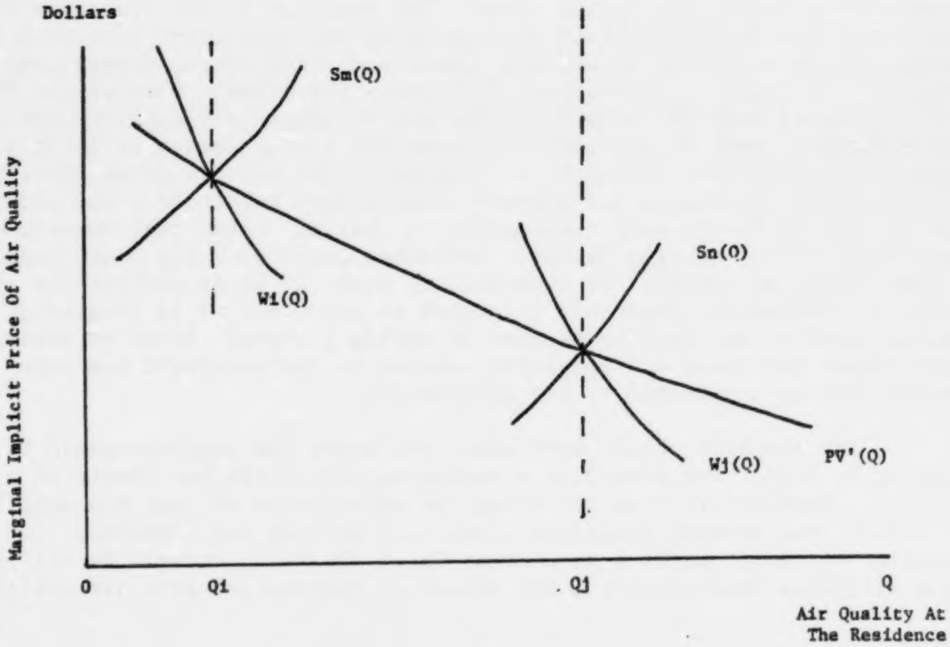
Dollars
Sm(Q)
Marginal Implicit Price Of Air Quality
Sn(Q)
Wi(Q)
Wj(Q)
PV'(Q)
0
Qi
Qj
Q
Air Quality At
The Residence

Figure 4.4b

The Marginal Implicit Price Function for Air Quality at the Residence that puts him on the offer curve that represents the highest obtainable profits and at the point where the offer curve is tangent to the hedonic price function. Hence supplier m is at point A while supplier n is at point B. The different offer curves for different suppliers represent differences in the resources, material, land, and technology available to each.

For there to be a trade off between prices and air quality, as is illustrated by the two offer curves shown in Figure 4.4a, air quality at the residential site must affect the costs of supplying the residence. It is clear that this would be the case for an attribute such as the number of rooms. An increase in the price of the residence that the supplier could obtain would compensate him for the additional cost of supplying an additional room at each residence, hence more rooms would be offered at higher prices. It is not clear, however, that air quality at the residence is under the control of the residence supplier. Harrison and Rubinfeld (1978) assume that air quality at the residence is exogenous and thus unresponsive to changes in the price of residences. Freeman (1979a) points out that this assumption is only partially valid.

> The number of houses of a given air quality can be increased either by an improvement in air quality over the urban area, or by increasing the number of houses available in the region of given air quality. With present institutional arrangements, the former can be assumed to be unresponsive to price; but the latter is likely to be somewhat price elastic [responsive]. (Page 127.)

This is an empirical question to which we do not as yet have a satisfactory answer. The degree to which supply adjustment is possible will depend on the time frame in question. Inelastic supply may be a reasonable assumption for the short run.

In Figure 4.4a only two pairs of supplier offer and household bid curves are shown, but the hedonic price function is actually formed by the tangencies of such curves representing the entire range of households and suppliers. These tangencies represent the equilibrium points where supply equals demand at property prices and residential site air quality levels that will be stable as long as there is no change in supply or demand conditions. Figure 4.4b shows the WTP curves for households i and j, the marginal cost curves for suppliers m and n and the marginal implicit price function for air quality at the residence. These are the first derivatives of the corresponding functions in the upper half of the figure with respect to air quality (i.e., $PV'(Q)$ represents the rate of change in property values with respect to air quality).

The functions the analyst must identify to estimate the benefits of a non-marginal change in air quality are the WTP functions.[17] It is usually postulated that a consumer's willingness to pay for a good is a function of the quantity of the good and the consumer's income and tastes. In the case of residential site air quality Freeman and Rosen suggest that:

Wi = W(Qi, Mi, Zi1,...,Zin,Si1...Sim)

where:

Wi = household i's willingness to pay for Qi

Qi = the level of air quality at household i's residence

Mi = household i's income

Zi1,...,Zin = other characteristics of household i

Si1,...,Sim = other attributes of household i's residence

can be estimated by regressing the observed marginal implicit price of residential site air quality or pollution for each household against the residential site air quality or pollution level, household income, and other household and property characteristics. Some of the other household characteristics that might influence WTP are size, age, and education. Very little work has been done to date to determine whether any property characteristics other than air pollution significantly influence willingness to pay for air pollution. Most of the studies that have estimated willingness to pay for air pollution have used a linear or log-linear functional form.

This procedure is complicated by the fact that the marginal implicit price for residential site air quality is determined by both supply side and demand side influences. The impact of the supply side must be accounted for or the analyst cannot be sure that WTP is being accurately estimated. This identification problem occurs whenever there exists a simultaneous relationship, such as supply and demand, of which only the outcome of the interaction is actually observed.

There are two special cases that make the identification of the WTP function easier. One is if all households have the same income, tastes, etc., so that they all can be represented by a single WTP curve. Then the WTP function is the same as the marginal implicit price function. This is the implicit assumption made by Ridker and Henning (1967) when they estimate the benefits of a reduction in air pollution by taking the change in marginal implicit price associated with the air pollution reduction at each property times the number of households affected. This assumption, however, is probably not valid in most study areas because households differ significantly in income, size, tastes, etc. If WTP functions are actually different from one household to another, as shown in Figure 4.4b, the assumption of identical WTP will overstate the true benefits of a reduction in air pollution and understate damages of an increase in air pollution.

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[17] Note that the willingness to pay curves in Figure 4.4b are income compensated because they are derived from bid curves along which utility is constant. Though these provide theoretically preferable measures of welfare, in practice the ordinary willingness to pay curves may often serve as approximations of these.

The second special case is if the supply of residential property at each level of air quality is unresponsive to changes in price. This ignores the possibility that the supply of residential air quality can be changed by changing the number of residences located in an area with a given level of air quality. However, the fixed supply assumption may be a reasonable assumption, especially in the short run, because supply adjustments in the housing market typically take years.

Another possible solution to the identification problem is to simultaneously estimate both supply and WTP functions. Nelson (1978) takes this approach and specifies a supply function. He postulates that the supplier's offer price for residential site air quality is a function of the level of air quality at the residence, the census tract population density, and time required to reach 75 percent of metropolitan employment from the residence. He reasons that suppliers bid a portion of a fixed total supply of metropolitan land away from other users and that their bids are higher when air quality is better. Freeman criticizes this specification of the offer function because it focuses on the trade off between industrial and residential land uses while not considering changes in residential density, which may influence the amount of housing available at each air quality level. Witte, Sumka, and Erekson (1979) have examined some of the supplier characteristics that may be important in determining the supply of housing though their housing market study does not specifically consider air quality. More work needs to be done in this area.

The procedure, as described above, that has been used in the most currently published hedonic price studies to estimate WTP has been recently criticized by authors in this field, informally and at professional meetings, though the discussion has not yet appeared in publication. The argument is that by estimating a hedonic price function from cross-sectional data of a single housing market, the analyst has only identified the marginal implicit price function and thus has only one point on each WTP function. To illustrate this problem, consider an urban area where there are three types of households differentiated only by income. Hence all the households will fall on one of the three WTP curves shown in Figure 4.5. Even if we assume that the supply of housing is fixed at three different levels of air quality, Q1, Q2, and Q3, we cannot identify unique willingness to pay curves from the information contained in marginal implicit price function, PV'(Q), because all we have are points A, B, and C which may be consistent with any number of willingness to pay curves. However, if we have a second marginal implicit price function, PV'(Q)*, from another time period in the same urban area or from another urban area, and if we can assume that the residents of the second time period or urban area can be divided into the same three household groups (or are different in ways for which we can account), each of the WTP curves can be identified because there are now two points observed on each.

Therefore, this second step of estimating WTP as executed in the currently published hedonic property value studies, such as those described in Chapter 6, is probably not yielding reliable WTP functions, but only modifying the information contained in the estimated hedonic price function. In most cases the functional form of the hedonic price function probably dominates the relationship between the marginal implicit price of air pollution, which is used as the dependent variable in the WTP function, and the level of air pollution, which is the primary explanatory variable in the WTP function, because a nonlinear functional form implies that the marginal implicit price is a specific function of air pollution. New approaches that use data regarding shifts in the marginal implicit price function over time or across several different housing markets may eventually alleviate this problem.

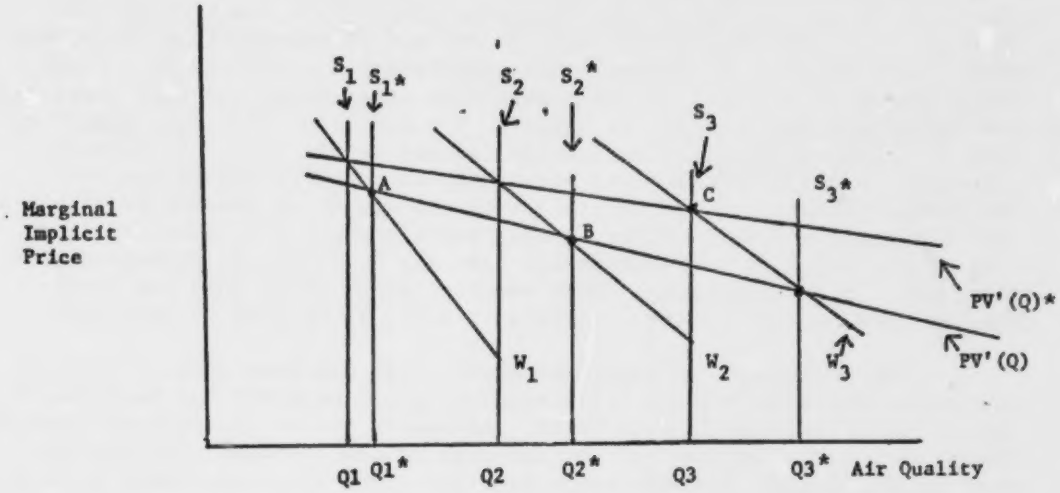

Figure 4.5

Identification of Willingness To Pay

Freeman (1979a) suggests that benefits can be approximated from the marginal implicit price function to avoid the difficulties of estimating the WTP functions. This is illustrated in Figure 4.6. The marginal implicit price function, PV'(AP) is known, but the WTP function, Wi(AP), is not. If air pollution decreases from AP1 to AP2 true benefits to household i would be given by the area ABFG. The first possible assumption is that WTP is constant from AP1 to AP2 implying that it is horizontal at point B. Benefits would then be area ABCG. This assumption would lead to an overstatement of true benefits and conversely, would understate the damages of an increase in air pollution. A second possible assumption is that the marginal implicit price function is the WTP function. As was previously mentioned this implies that all households can be represented by one WTP function. Benefits would then be area ABEG which would overstate the true benefits of the air pollution reduction less than the constant WTP assumption. Both of these assumptions would allow the analyst to set an upper bound on benefits or a lower bound on damages of a change in air quality.

A third possible assumption is that WTP is zero when air pollution is zero and that the WTP function decreases linearly from point B to the origin. In this case estimated benefits would be area ADEG. In the depicted situation this would overstate benefits less than the constant WTP assumption. However, depending on the slope of the actual WTP curve this assumption could also understate true benefits. Though this assumption would not establish an upper or lower bound on benefits or damages it may be useful in cases where the estimated marginal implicit price function has a positive slope.

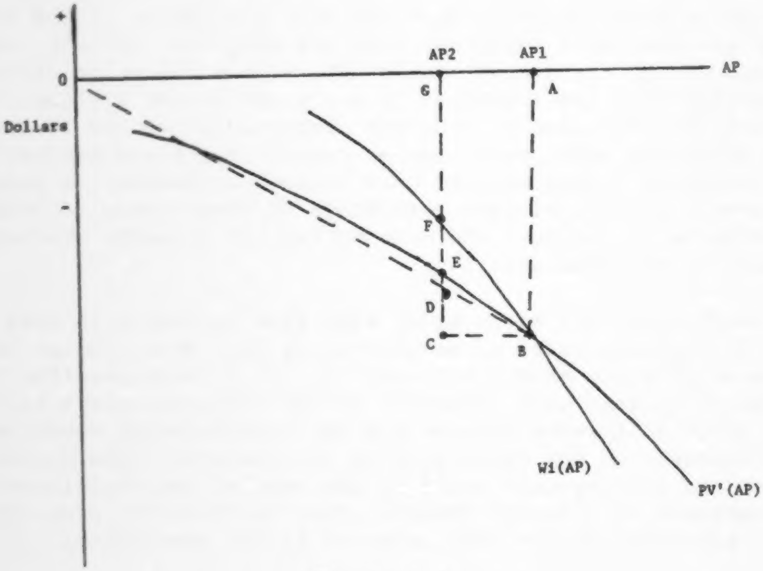

Figure 4.6

Approximating Benefit Measures From The Marginal Implicit Price Function

Source: Freeman (1979a) p. 145.

4.3.3 Variations in the Property Value Approach

There are two variations to the property value approach that have been used to estimate the value of air quality from the residential property market. The first is the matched pairs technique developed by Brookshire et al. (1979) in their study of the South Coast Air Basin of Southern California. This study has been replicated by Loehman et al. (1980) for the San Francisco Bay area. This technique merely adds a preliminary step to the hedonic price technique by selecting pairs of neighborhoods that are similar except for their air quality.

The other variation is the residential location model developed by Polinsky and Shavell (1976) and implemented by Polinsky and Rubinfeld (1977) and by Smith and Deyak (1975). From this model an equilibrium rental price function is derived that gives the relationship between housing rents, travel distance to the central business district (CBD), neighborhood amenities, and household income that will sustain equilibrium in residential choice. If a specific form for the utility function is assumed, the estimated parameters of the rent function can be used to identify the utility function from which benefit measures can be directly estimated.

Matched Pairs Technique

One of the problems with the hedonic price approach to estimating the value of air quality is that there are many influences on the price of property that are much more important than air quality. Ideally, in a cross-sectional study, the analyst would like to see the price differences between properties that are identical in every way except air quality. More realistically, variation in property characteristics can be reduced by purposefully selecting some properties or census tracts and excluding others from the study. Many studies have limited themselves to census tracts that have a certain minimum percentage of owner-occupied houses or used other criteria to cut down the wide variety of property characteristics that exist in an urban area.

The South Coast Air Basin study went even further with this selection process by choosing pairs of neighborhoods that were similar in as many respects as possible except air quality. If it were possible to select matched pairs that were identical in all respects except air quality the property price difference between the two neighborhoods would be entirely attributable to the difference in air quality. This dollar difference per air quality unit would be the same as the coefficient of the air quality variable in a linear hedonic price function for property values, as long as air quality were measured in the same units.

In practice it is probably not possible to find perfectly matched neighborhood or property pairs so that the price differences will reflect other differencs in addition to the air quality differences. This is supported by the South Coast Air Basin study, which found that the price differences between the matched pairs were larger than the price differences attributed to air quality in a hedonic price function estimated for the matched properties. The matched pairs approach, however, when used to select properties for a hedonic price study, has the the advantage of potentially eliminating some of the non-quantifiable differences between neighborhoods that are not captured in the hedonic price function and can bias the measured influence of air quality. There are likely to be elusive property characteristics that are important to households, but are not easily captured by measures such as the number of rooms and distance from the CBD. Careful matching of neighborhoods will hopefully hold constant some of the characteristics that are difficult to quantify. Also, because the effect of air quality on property values is small relative to other determinants of property value, reducing the variations in other attributes will help to isolate the effect of air quality.

Residential Location Model

This model is based on the models of the residential location decisions in an urban area, which postulate that the household's residential location choice depends primarily on the distance from the CBD and the amenities at the residential location. Air quality is one of these amenities. If the effect of each amenity on the location decision can be explained, then the demand for each amenity can be identified. What permits identification of the demand for amenities even in the absence of a market is that land is differentiated across the urban area by amenities.

The residential location model postulates that the household's utility is a function of consumption goods, housing services, and amenities at its residential location. Thus for a city where all workers are employed in the CBD and all households and residences (for each household class) are identical, the equilibrium rental price of residential property is demonstrated to be a function of the distance from the CBD, amenities at the residential site, household income, and the equilibrium level of utility.

In application, a specific functional form is assumed for the utility function from which a specific rental price function is derived. Households are grouped into classes according to income and assuming that all households in a given class have identical utility functions the rental price function is estimated for each class. The estimated rental price function must also account for differences in the quantity and quality of housing that do exist. This procedure also assumes that households are sufficiently mobile to ensure that equilibrium levels of utility are attained.

Depending on the specific form of the utility function from which the rental price function is derived, the estimated parameters of the rental price function can be used to identify the parameters of the utility function. When the utility function is known, EV and CV measures of welfare changes caused by changes in amenities can be directly estimated. The hedonic approach, on the other hand, estimates WTP functions from which measures of OCS can be obtained. The functional form used to estimate the WTP function has specific implications about the nature of the utility function, but it does not impose any one form on the utility function.

In application, the residential location model has many of the same difficulties as the hedonic price technique as well as requiring several additional and more artificial assumptions about the nature of housing, households and the urban area. Polinsky and Rubinfeld (1978) and Smith and Deyak (1975) use the Cobb-Douglas form for the utility function. The rental price function derived from the Cobb-Douglas utility function is a log-linear form.

4.3.4 Strengths and Weaknesses

The major strength of the property value approach is that it uses actual market data that reflect what people have actually spent to obtain various levels of air quality. This is an important advantage over contingent market approaches that ask people what they would spend but do not require them to part with their money. However, the use of property values to estimate the value of air quality is limited by what property value studies can measure and when they can be used. Most importantly, property value studies are restricted because they rely on data that were not collected for this purpose. Several specific limitations are delineated in this section.

When Property Value Studies Can Be Used

Property value studies can be used to estimate benefits of air quality only under certain conditions. First, there must be fairly consistent spatial variation in air quality. If air quality is the same over an entire urban housing market its effect on property values cannot be separated from other influences on property values. Not only must air quality vary from one residence to another, but the variation must be stable enough over time that a measure of average air quality varies from residence to residence. In other words, if air quality varies such that one day neighborhood A has clean air and neighborhood B has dirty air and the next day neighborhood B has the clean air and A the dirty, no differences in property values between the neighborhoods can be attributed to air quality. Fortunately there are often fairly stable patterns of air quality over an urban area, such that air quality is usually worse in the central business district (CBD) and in whatever direction from the CBD that the wind usually blows. However, property value studies may be of little use for estimating the impact of the regional haze that is homogeneous over large areas as occurs primarily in the eastern U.S.

A second condition is that differences in air quality impacts must be perceived by individuals to be reflected in property values. The damages of poor air quality include health effects, property damage such as corrosion and dirt, and aesthetic impacts. There will not be a problem if households do not correctly attribute the impacts to air pollution as long as households perceive the differences between residences. For example, if one neighborhood seems dirtier and less lushly vegetated than another, property values may reflect these differences even if people do not realize that they are the result of air pollution. However, there may be impacts that are not perceived at all. For example, carbon monoxide is a colorless, odorless pollutant that causes acute symptoms only in high concentrations. However, there may be health effects of long-term exposure to low concentrations that people do not attribute to carbon monoxide exposure. Additionally, property value studies presume that individuals' perceptions of air quality are reasonably correlated with the technical measures of air quality that are available to the researchers.

A third condition is that people must be sufficiently mobile for property values to reflect current air quality conditions and for the the implicit price of air quality to reflect the household's WTP. Consider the process whereby a change in air quality would cause property values to change. If air quality in a particular neighborhood is improved property values would reflect the change only as new people were attracted to the neighborhood and caused housing prices to go up. If moving costs are high or for some other reason people are reluctant to move they may tend to stay at a less than optimal location given their preferences, income, etc. Hence, there may be a significant lag between changes in a housing market and the complete adjustment to these changes. It is not clear how serious this problem is in practice, but the validity of the property value approach to air quality benefit estimation may be lessened in housing markets that have been subject to recent and/or rapid change. This is less of a problem when actual sales data are used, which requires only that buyers choose an optimal residential location given conditions at the time of the purchase and that there is enough competition among buyers to force prices to equal marginal willingness to pay.

A fourth condition is that it must be possible to separate air quality from other neighborhood amenities for property value studies to correctly determine price differences attributable to air quality differences. Sensitivity tests in several studies have shown that the air quality coefficient changes significantly if variables correlated with air quality are omitted. Similarly, correlations among different air quality measures may impede the attempt to isolate the visibility damages from the health damages of air pollution in a property values study. However, the empirical studies have not yet addressed the question of whether visibility effects can be separated from the other effects of air quality.

A fifth condition is that the necessary data must be available. Property value studies cannot always be used to estimate the benefits or damages to be expected from a future change in air quality. Changes that have not yet occurred will not be reflected in property values unless they have been anticipated by households. In sparsely populated areas there may not be enough private residential properties and therefore not enough data to estimate a hedonic price function. Improved research tools may eventually allow WTP functions that were estimated for one area to be transferred to another area given similar air quailty conditions and certain assumptions about similarities between the two populations. If reliable WTP functions are estimated it would also be possible to predict the impact of air quality changes that have not yet occurred by extrapolating beyond the current air quality levels in the study area. Such improvements may eventually ease the restrictions caused by the data requirements of the approach.

What Property Value Studies Can Measure

Even under ideal circumstances, a residential property value study can probably measure only certain aspects of air quality benefits. First of all, residential property value studies can measure only the impacts of air quality at the residential site. Because most people do not spend all of their time at home, they will experience the air quality at other locations, such as their work place, which will not influence the value of their residence. It is possible to apply the hedonic price technique to commercial and industrial property and to wages, but research experience in these areas is at this time quite limited. Future research may soon reveal additional evidence about the nature and magnitude of air pollution impacts at the work site, but most currently available evidence concerns impacts only at the residential site.

Using property value differences to estimate benefits of air quality usually assumes that prices and quantities of other things are not affected by changes in air quality. If this assumption is violated, the change in property values may not reflect the household's full willingness to pay for air quality. People may respond to changes in air quality in ways that do not affect the value of their residences but affect the value of other goods. For example, the demand for some outdoor activities, such as golfing and jogging, may be affected by changes in air quality causing changes in the prices of goods associated with these activities that are not reflected in housing values. If this occurs to any great extent, property value studies can capture only part of the benefits of a change in air quality.

Property value studies will capture only part of the benefits if the assumption of weak complementarity, defined in Section 2.5, does not hold. Most property value studies have assumed that the marginal value of air quality in a particular neighborhood is zero for those who do not live there. Under most circumstances, this may be a reasonable assumption, but there may be times when it is not valid, such as when the view from one neighborhood is affected by the air quality in another neighborhood. Counting only the benefits to the residents of the second neighborhood would then understate the benefits of an air quality improvement there.

In some cases this limitation can be overcome by enlarging the area considered is assessing air quailty impacts on the household. However, if substantial impacts are caused by air quality well beyond the neighborhood in which the household resides the property value approach may fail to capture such impacts. This may frequently be the case with visual impacts because visual quality is not only influenced by the air quality where the viewer is located but is also influenced by the air quality between the viewer and objects that are viewed.

Property value studies may be limited in their ability to measure air quality benefits at mandatory Class I Federal areas and other recreational areas. Property at a recreational site is often publicly owned and therefore not subject to the market conditions that would bring prices in line with benefits. However, even where the private property market is sufficiently extensive there are problems posed by the fact that most people spend only a small fraction of their time at a recreational property. Health effects, in particular, may not concern the individual who will be in that location for only a few weeks out of the year. Aesthetic effects, on the other hand, may influence recreational property values significantly, since poor visibility, for example, may seriously detract from the enjoyment of the recreational experience. Another serious drawback for property value studies in recreational areas, where hikers, campers and picnickers make up a large proportion of the area users, is that property value studies will pick up air quality impacts only on those who own or rent property.

An example of an application of the hedonic price technique to recreational property is provided by Wilman (1981). She applies this technique to recreational rental property on Cape Cod to estimate the damages of beach debris to the recreational experience. Cape Cod has a fairly well developed private property market, and the condition of the beaches has a direct impact on the recreational experience. Under these circumstances this approach is applicable.

Property value studies, even in recreational areas, will usually capture only the activity value of the air quality at that location. This is because property values will reflect how much people are willing to pay to live, vacation, and to some extent, be able to visit an area under its current air quality conditions, which represents activity values at that location and possibly some option value to be able to visit that site in the future. How much they would be willing to pay to know that somewhere the air is clean and to have the option to go there at some future time will not be reflected in any property values.

Because a residential property provides a stream of services over an extended period of time, the purchase price of the property is determined by the present value of the expected future stream of benefits. Therefore the price of the property is not only influenced by current air quality conditions but is also influenced by the expectations concerning future conditions. For example, a property value study to determine benefits of current air quality in an area surrounding a long discussed and well publicized proposed coal fired power plant site may be thrown off track if expectations of future air quality degradation have already begun to influence property values.

4.4 Introduction to Alternative Approaches For Measuring Economic Benefits of Visibility Aesthetics

The emphasis of this chapter has been to present the best methodologies that are currently being practiced and have been subjected to some degree of validation either through repetition or by simultaneously applying other techniques to obtain comparable results. Several alternative approaches are and will continue to be developed. This section briefly introduces a few of these alternatives.

4.4.1 Ranked Attributes/Market Share

This technique has been used to determine characteristics of demand for market goods.[18] It is currently being developed as a contingent market technique to analyze the demand for air quality through a survey approach where respondents are asked to rank order choices of alternative sites, for instance Class I area recreation sites. The alternatives have different combinations of attributes, including the level of air quality, which may be depicted in photographs; the market costs, such as entrance fees; and the locational attributes, such as congestion and travel distance. By evaluating how a particular site ranks under different visibility and other site conditions, it is possible to see the changes in market shares each site will capture, or the changes in the probability a particular site will be the most desired site, and to evaluate the demand for a site as a function of these conditions.

A principal advantage of this approach is that the respondent is not forced to directly put a dollar value on visibility; but rather reveals the value of visibility indirectly, and perhaps less objectionably, through the ranking of sites with alternative levels of air quality, prices and other attributes. The effects upon a site's ranking from changes in air quality and prices can be traded off to indirectly determine benefit measures. The approach may also prove to be a useful form of verification of other methods.

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[18] This approach has been used primarily to evaluate travel mode-choice using actual market data (McFadden 1974; and Domencich and McFadden 1975). Douglas Rae at Charles Rivers Associates is currently attempting to value alternative levels of air quality at Class I areas using the approach in a study funded by the Electric Power Research Institute.

Some of the problems with this approach include the potential need for a great many complicated alternatives to be ranked to obtain any precision in the estimates. If each alternative has several attributes simultaneously changing, respondents may be unable to focus upon all of the changes. If instead, respondents focus upon changes in only one attribute this will increase measurement error in the evaluation of the other attributes. Further, if the alternatives are not clearly understood, which may be the case for individuals who have never visited the alternative sites, the ability to rank alternatives accurately is seriously impaired. This problem is similar to that of hypothetical bias. The approach, as developed thus far, is not applicable for the derivations of option and existence values.

A pretest of this technique was carried out at Mesa Verde during the summer of 1980. By determining how the probability that a desired site will be chosen is affected by air quality, prices and entrance fees, compensating surplus measures of benefits are obtained. This is done by holding all variables constant and determining how prices must change to offset air quality changes such that the probability the desired site will be chosen from all competing sites remains constant. The pretest values, ranging from $4 to $5 per day per person to preserve clear air versus plume blight, and from $8.45 to $10.74 to protect against severe regional haze (using the best fitting statistical specification), are of a similar order of magnitude to other benefit measures obtained in the Four Corners region. Although the pretest encountered many survey problems, the technique holds promise as a useful tool.

4.4.2 Travel Cost and Site Substitution Approaches

The travel cost method has been used extensively to estimate the demand for benefits of recreation activities, particularly at specific recreation sites. The travel cost approach, suggested by Hotelling, initially developed and applied by Clawson (1959) and Clawson and Knetsch (1966), and refined by a great many authors,[19] recognizes that to use the services of a recreation site, users not only incur expenses of entry fees and equipment, but must get to the site. The cost, or price, to an individual of using the services at a recreation site will vary according to the travel time and expenses incurred getting to the site. The further away users are from a site, the greater the implicit price of using the site.

The simplest Clawson-Knetsch (C-K) travel cost approach may be implemented by assuming there is only one site to be considered by recreationists and by assuming the supply of services (recreation visits) at the site is infinite at the travel cost price (travel cost plus entrance fees and other user costs) for each individual. Next, by establishing visitor use rates for recreationists from different distances from the site, a regression analysis of the visitation rates as a function of the travel cost measure of price and socioeconomic characteristics of the recreationists from different distances is used to estimate a demand curve for the site services. This is frequently done at an aggregate level using visitations at a site for recreationists from different origins. It may also be performed with micro-level (household), data on recreation behavior when such data exists.

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[19] More detailed reviews of the travel cost method may be found in Freeman (1979a), Smith (1975), Dwyer, Kelly and Bowes (1977), and Knetsch (1974) among others.

In many typical applications of the C-K travel cost approach a demand curve is estimated relating the travel cost price to the actual number of visits for a particular site at a single point in time. Because environmental quality does not change at any point in time, these variables are often not included. Next, the benefit of having versus not having the park, given current conditions, are calculated as equal to the consumer surplus derived by recreationists, i.e., the difference between the demand (WTP) curve and the entry fee and other travel costs. Because our interest is with the changes in the levels of environmental quality variables rather than the existence of the site, this simplified approach will not yield the desired information.

A generalized presentation of the travel cost demand estimation for the ith individual (or for all individuals from the ith origin) for each jth site, which includes environmental quality variables and which may be used to address the benefits from changes in environmental quality is:

$$Vij = Vij\ (Pe, Px, Dij, c, tij, di, Sih, ei, AQ, Mi, Zi) \qquad (1)$$

where:

Vij = number of visits by individual i (or by individuals from i) to site j

$Vij(.)$ = visitation functional form which may vary across all j sites and all i individuals

Pe = vector of money prices of entry (possibly zero) to the various sites

Px = vector of private goods prices

Dij = vector of round trip distances from residence of individual i to the various sites j

c = unit cost of travel miles

tij = vector of travel times to the various sites j for individual i di = cost of travel time

Sij = on site time for i at site j

ei = on site value of time

AQ = vector of air and other environmental quality measures of the various sites

Mi = money income of individual i

Zi = vector of other socioeconomic variables

Demand for recreation visits at each site is a function of the travel costs and entry fees, the money cost of time in travel and recreation, socioeconomic variables, all prices, and environmental quality variables at all sites. Economic theory will often constrain the ways these variables enter the Vij(.) function. Distance and unit travel costs are included to represent the out-of-pocket costs, while travel time and site time are included to represent the opportunity cost of getting to and staying at a site. Environmental quality variables at all sites are included because if these conditions are known in advance by the recreators it is likely that they will influence the choice of sites and rate of activity.

What is desired is a measure of how changes in air quality affect demand for recreation at the affected site. If a recreation demand curve as a function of air quality can be appropriately estimated for a site, then consumer surplus can be determined in the usual way as the difference between demand (WTP) and expenditures: The effect of changes in air quality upon demand, and therefore consumer surplus, provides a benefit measure of the air quality change.

The strengths and weaknesses of the travel cost approach have been discussed at length by other authors (see footnote 19). Strengths are that the technique focuses upon well established behavior for which data often exist or are easily obtained (for example, through license plate surveys of actual visitors) and once the demand estimation is performed, benefit measures are readily obtainable.

Among the unresolved problems in all applications of the travel cost approach is the measurement of the cost of time. Time spent traveling to, and recreating at, a site involves opportunity costs of producing the experience in terms of other activities foregone. Yet the time spent traveling and recreating may be part of the desired experience. Ignoring the time cost of travel will bias the price elasticity of demand and WTP estimates. Further, the measures of travel time and travel distance are highly correlated and complicate the estimation procedure.

Other problems in the travel cost approach include difficulties in allocating costs for multi-purpose trips; the assumption that changes in travel costs have the same effect on recreation demand as changes in entry fees and other costs; handling capacity problems; and defining all variables and correctly specifying the demand relationship. The definition of the dependent variable is of particular concern because one needs to have a consistent measure of the use of the recreation facility. Simply grouping together trips of different lengths, in terms of recreation days at the site, raises a problem of an inconsistent and somewhat ambiguous measure of use. Yet, using recreation days is problematic because each day is subject to different travel costs. An additional problem is that recreation days or recreation trips may not capture that aspect of the experience that is actually demanded. A potentially more desirable approach is to determine the demand for the characteristics of the recreation experience at a site. Two approaches focusing upon the demand for attributes at a site are the contingent travel cost and hedonic travel cost procedures discussed below.

The travel cost approach is limited in benefit analysis because by analyzing the behavior of actual users it obtains activity values of users at a particular site and does not obtain option or existence values by users and non-users. Also, the technique is site specific, which, without specification of how changes in characteristics of the recreation site individually and in combination with changes in air quality affect the demand for recreation at a site, limits the tranferability of results. For example, as is the case with all dissimilar sites such as most Class I areas, estimates of the effect of changes in air quality upon the value of recreation in the Grand Canyon would be very difficult to transfer to any other site. To be accurate the specification of demand must also account for changes in environmental conditions at the site of interest and at competing sites that may affect demand. This can be a rather difficult task.

As yet there have not been any empirical applications[20] of the travel cost approach to the problem of visibility benefit analysis. Two general types of travel cost approaches could be used to measure the effects of changing air quality upon demand--surveys obtaining actual visitation data and surveys obtaining hypothetical visitation data. In the first, historical travel cost data and actual visitation data at a site of interest and supporting data for the site and all competing sites could be obtained, from which the effect of changes in air quality at the site upon demand for recreation could be determined using a variation of Equation 1: Vi=Vi(.), for all i given j = the site of interest. This would yield site-specific air quality benefit measures. Cross-sectional data of actual visitation rates at a group of sites could also be used to estimate a fixed form of Equation 1, Vij = Vij(.), for all i, j. This, however, assumes the variables of interest are the same, and affect visitation in the same manner across all sites, thus yielding only an average relationship between changes in visibility and recreation demand at all sites examined.

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[20] The approach was being attempted as part of the summer 1980 study of visual aesthetic impacts of proposed mining operations outside of Bryce Canyon National Park (U.S. NPS 1980). The results have not yet been released. Devine and Smith (1981) have addressed theoretical issues associated with applying travel cost methods to visibility benefit analysis using the household production function approach to consumer behavior. They illustrate how the standard travel cost model and the hedonic travel cost approach (discussed in this section) are special cases of their generalized presentation.

Using historical or cross-sectional data is problematic because visibility conditions are often very similar across competing sites and through time, and are less of a demand-determining factor than are the unique characteristics of the sites and other factors that may vary through time or across sites, such as water quantity or quality. Consequently, estimates of how changes in visibility conditions affect demand are likely to be inaccurate unless a substantial data base, including measures of all other important characteristics at each competing site in each time period, is compiled and used in the demand estimation. Work in this direction has been initiated to quantify those aspects of the experience valued by recreationists. (For example see Stankey (1972, 1973); Brown, Driver and McConnell (1978); Lucas (1964); Lucas and Stankey (1973); Hendee et al. (1971) among others.)

For these surveys of actual behavior to be effective for visibility benefit analysis, the proposed change in air quality must also have occurred, have been accurately defined and measured and have been recognized by recreationists either at the site or across sites. If recreationists are either unaware of visibility conditions at recreation sites or unaware of prevailing conditions on their desired recreation days, a function relating visitation to air quality will underestimate benefits from control because the air quality elasticity of demand will understate what responses would have occurred had recreationists possessed full information. Equivalently, this approach will not appropriately measure benefits or damages to those individuals who recreate at a site with less than their desired air quality conditions due to the lack of information. Appropriate implementation of this travel cost approach implicitly assumes that recreationists have full knowledge of conditions or requires a model of their expectations. While such assumptions may be plausible in some cases, in general there is little evidence to support applying them to air quality, particularly at distant national parks.

These approaches will yield much different benefit estimates if the changes in air quality have occurred uniformly across all competing sites in each time period rather than only at the site of interest. For example, if air quality decreases at only one of many competing sites, individuals may substitute to the services at other sites. On the other hand, if all competing sites are affected equally there is little incentive to substitute across sites. Therefore, one would expect the substitution away from the site of interest to be greater when only one site is affected than when an entire region is affected.

A second approach would be to survey individuals as to their recreation travel behavior given alternative hypothetical scenarios of environmental conditions both at the site and at competing sites. This "contingent travel cost approach" has been successfully applied by Thayer (1981) to examine the effects upon recreation patterns from geothermal development in the Jemez Mountains of New Mexico. Applied to air quality this approach attempts to estimate benefits by determining travel costs that respondents would incur to recreate at alternative equivalent sites given increasing air quality degradation at the surrent site. A utility maximizing individual is assumed to recreate at the nearest outdoor facility if all areas are equivalent in all other competing aspects and to recreate only at the next nearest area if there is a significant deterioration at the closest site. By asking detailed questions on site attributes, expected activity rates and selected locations coupled with the costs of substituting locations, the value of damages associated with alternative levels of air quality can be inferred.

The contingent travel cost approach has strengths in that all other factors can be held constant by the scenario development so that changes in recreation patterns are influenced only by the change in environmental quality at the site of interest. The difficulties are much the same as contingent market approaches. Uncertainties about alternatives may cause respondents to be unable to estimate their rate of substitution among the alternatives and the lack of alternatives in some situations may limit the ability to accurately measure benefits of improved air quality. Finally, as discussed for the bidding methods, the alternative conditions must be carefully defined and presented to respondents.

Substantial work has been done to determine the demand for recreation experiences, but little research has been done on the characteristics that make up those experiences and how changes in these characteristics affect demand. Brown and Mendelsohn (1980) have addressed this problem by developing a promising "hedonic travel cost approach". In this approach recreationists are assumed to be willing to incur different levels of cost to recreate at different sites because of the different levels of the characteristics supplied at the sites. The combination of characteristics, costs, and socioeconomic characteristics of the individual can be examined, as in the property value approach, to determine the demand for the characteristics.

The hedonic travel cost approach asserts that given fixed trip costs plus increasing costs associated with increasing expenditures in distance traveled and time spent, an individual will choose to travel further away to recreate only if more distant sites provide, all else fixed, higher levels of desired characteristics. Therefore, by regressing travel costs from one point of origin to each of several sites on the characteristics at each site, a hedonic price function, which the authors label a value function, of characteristics is estimated (i.e., prices of characteristics are origin specific, not site specific). For each point of origin the marginal value of a unit of characteristic is the partial derivative of the value function as in the hedonic approach. A separate hedonic value function is estimated for each point of origin to many alternative sites. The demand for the characteristic across all origins and destinations is estimated by regressing the average level of characteristics demanded by different types of recreationists on the characteristics prices for those recreationists.

Brown and Mendelsohn (1980) apply the hedonic travel cost technique to data from a survey of Washington state steelhead trout fishermen. The survey revealed hours and distance traveled, origin and fishing location, number and length of trips and a 1 to 10 evaluation for each of the chararcteristics of the fishing site. Two hedonic value functions of travel costs versus the levels of characteristics at alternative sites were estimated for each point of origin--one function for miles traveled and one function for time traveled. Linear hedonic price functions were used in this effort, although not required by the method. Next, the authors estimate the demand for different length trips (one day, two or three days, etc.) as a function of socioeconomic characteristics of the recreationists and the implicit prices of characteristics. Finally, the demand for site characteristics across all sites by origins is determined by regressing the average level of characteristics for each trip length on the price of characteristics and socioeconomic variables.

This hedonic travel cost approach could be applied to determine air quality values but faces many of the same problems of the C-K approach. In particular, the measure of air quality must be more carefully defined than by the simple 1 to 10 scales used in the Brown and Mendelsohn study because such ratings by non-professionals may tend to be inconsistent (see Chapter 3) and of limited usefulness in benefit-cost analysis for specific levels of pollution control. It is also necessary to more carefully define all relevant characteristics of a site, as in the property value studies, rather than just a few as in the Brown and Mendelsohn study. Finally, this approach requires the use of a single attributes to visitation demand function which is assumed to be homogeneous across all sites for each origin. This first requires defining all relevant sites for the first stage equations. Further, a linear model maintains that there is one price for each attribute in the market, defined by the chosen array of relevant sites. A non-linear hedonic price schedule would allow different prices of the attributes at each site. Nevertheless, the hedonic price relationship is assumed constant across all relevant sites. In practice, this may be a serious limitation to the use of this approach in unique recreation areas where the effect of air quality upon demand and WTP will vary substantially with the unique scenic vistas and would be difficult to quantify in a cross site regression analysis. The approach would be most useful for recreation experiences across sites that are highly similar such as beach use, inland fishing, or skiing so that benefit measures could be confidently transferred from site to site.

4.4.3 Household Production Function Approach[21]

This approach may use market data or survey respondents to determine the rate and location of specific activities; characteristics of the site frequented, such as air quality and congestion; the activity engaged in; and the level of expenditures related to the activity. In the survey approach, alternative scenarios for air quality are presented, and respondents are asked how they will change their rates of activity, location and expenditures. Much as in the site substitution and travel costs approach, changes in expenditures are used to generate demand curves and damage functions.

Because successful analysis of air quality issues with this approach necessitates potentially complex data on trade-offs and expenditures, this may diminish the accuracy of using surveys for this technique. Limitations on available secondary data may also limit the market approach for this technique.

4.4.4 Wage and Salary Differentials

Labor markets have been examined in an effort to derive values of urban amenities. Similar to the rationale for the property value studies, this examination of wage and salary differences is based on the supposition that individuals must be compensated in the form of higher real wages (higher nominal wages and/or lower cost of living) to accept disamenities where they live and work and, conversely, are willing to accept lower real wages to live and work in locations with positive amenities. Recent studies indicate that progress is being made toward the application of this approach to the estimation of the value of air quality, although a substantial amount of research is necessary before it becomes an accepted "best practice" for estimating visibility benefits.

Similar to the estimation of a hedonic price function for property values, some wage studies have estimated a labor market opportunities function from observations of actual wage levels and different amenity levels across several urban areas. This function is usually estimated separately for each occupational category. It represents the market equilibrium wage level and amenity or disamenity combinations that are available to individuals.

Each partial derivative of the labor market opportunities function with respect to an amenity or disamenity represents a marginal implicit price for the amenity or disamenity. It indicates how much additional wage an individual must give up to obtain additional units of an amenity, such as a pleasant climate or cultural opportunities, and how much additional wage they would be compensated to accept additional units of a disamenity, such as crime or air pollution. As with the property value studies, these marginal implicit prices represent the individual's marginal willingness to pay only for the amenity level at which he is observed. This is because the optimal location for the utility maximizing individual is where the amount of wages he must give up to obtain an additional unit of each amenity just equals the amount he is willing to pay for that additional unit. Hence, he is observed at the point where his WTP function crosses the marginal implicit price function for each amenity. However, because individuals have different tastes and preferences (i.e., different WTP functions), the observed wage differences statistically attributable to air quality differences will not be eqivalent to the individual's willingness to pay for non-marginal changes in air quality.

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[21] A variation on this approach was first attempted for air quality in Blank et al. (1977); however, numerous methodological problems hampered the effort. Another application for wildlife stocks can be found in Eubanks and Brookshire (1980). Ernie Manuel and Robert Horst, at Math Tech and under contract to EPA, are currently pursuing this approach for air quality issues with the use of market data.

The labor market opportunities function is determined by individuals' willingness to supply labor at different amenity-wage combinations and by firms' willingness to demand labor at different amenity-wage combinations. Both sides must be considered if willingness to pay for other than a marginal change in an amenity level is to be identified. Current studies have only begun to address the complexity of this interaction.

One of the primary difficulties faced by these types of studies is that air quality is only one of many minor influences that determine in what city an individual will choose to live. To isolate the effect of air quality the entire location decision must be explained. Property value studies must explain where a person chooses to locate within an urban area, but wages are influenced by the overall air quality levels an individual encounters in his entire living and working environment, not at any one site within an urban area. Hence, intercity comparisons are necessary to see how wages vary with different air quality levels.

Air quality is probably much less important in determining in which city an individual will choose to reside than in determining where in a particular city he will choose to reside. For example, households are probably more willing to move across town to be in a cleaner neighborhood than to move across the country. That this makes it very difficult to produce reliable air quality benefit estimates from intercity labor market data is supported by the findings of Smith and Deyak (1976). They found air quality measures to be insignificant in influencing property values across different urban areas, even though numerous studies have found a significant influence of air quality on property values across a single urban area.

Two examples of recent research efforts using labor market data are Rosen (1979) and Cropper and Arriaga-Salinas (1980). Rosen estimated a relationship between individuals' real wages and average measures of city amenities and disamenities across nineteen major urban areas for several occupational categories. He used occupational and personal characteristics from the 1970 Current Population Survey, which provides data on an individual rather than an average basis, to account for interpersonal differences in earning capacity. He then added measures of amenities for each urban area to obtain a relationship between wages and each amenity. Included were measures of air and water pollution, climate, crime, crowding, and market conditions. He used the results to construct quality of life indexes for each city. He did not attempt to go beyond estimating the marginal implicit price of air quality, but his results at that point seem plausible. A measure of suspended particulates was the most significant pollution variable. A one standard deviation increase in particulates (apparently 38 $\mu g/m3$ this case) was associated with a 1.7 percent to 5.7 percent wage premium. At the mean annual earnings of the sample, $9,000, this amounted to $153 to $513 per year.

In a theoretical section of the paper, Rosen demonstrates the joint adjustment of land and labor markets to variations in amenity levels. He postulates that utility is a function of consumption goods, residential space, and amenities, from which he derives indifference curves for the individual showing the trade-offs between rents and amenities and between wages and amenities that maintain constant utility. He does not attempt an empirical estimate of these relationships.

Cropper and Arriaga-Salinas (1980) used a somewhat different approach by developing a model in which proximity to input and output markets and property tax rates determine the locational pattern of industrial growth and consequently determine the demand for labor. From a log-linear utility function that allows for the possibility that amenities may vary across a single city, she derives a labor supply function for each city, the arguments of which are employment and amenities in each city. This labor supply function can be used to estimate the coefficients of the amenities in the utility function, allowing the derivation of consumer surplus benefit measures for a change in an amenity. The authors used a simultaneous estimation procedure to estimate the supply and demand for labor. The advantage of this approach is that both supply and demand sides of the labor market can be considered, but it requires specifying a specific functional form for the utility function, which is unknown.

The measure of air pollution used was sulfur dioxide. It was found to significantly influence the supply of labor for some, but not all, occupational categories. She cautions that this approach is quite experimental, but to illustrate how valuations of amenities can be derived she estimates that the present discounted value of a 30 percent reduction in sulfur dioxide, calculated for a person earning the median income in St. Louis in 1960, is between $418 and $489.

4.4.5 Voting Approaches

Many voting and demand-revealing processes could potentially be used in determining optimal quantities of, or the willingness to pay for, environmental goods, including air quality. While there has been little use of these approaches to date for valuing air quality, growing professional interest in them will undoubtedly lead to such efforts in the future. In this light, a few of these approaches are very briefly introduced with the recognition that considerable research will be required before any of these will become best practice for visibility benefit analysis.

In many of these approaches an attempt is made to have individuals reveal estimates of the desired quantity of a public good through various incentives, taxation schemes and group decision-making mechanisms.[22] One such approach, suggested by Portney (1975) for determining desired levels of for pollution control, is to ask individuals to indicate their preferred quantity of a public good given estimated costs of several alternatives and a specified tax share of the total cost. The utility maximizing individual will choose the quantity where his marginal cost, in terms of tax burden, equals his marginal return in terms of environmental amenities. This price (tax share) and quantity combination yields one point in each individual's WTP or demand schedule. If the costs or tax system, and therefore the price, is varied across individuals with similar socioeconomic characteristics the results can be pooled to derive demand curves for the environmental good from which the willingness to pay for changes, and income and price elasticities of WTP can be determined. It has been shown that under cetain conditions this approach may also reveal the economically efficient level of public good provision (see Bowen 1943 and Portney 1975).

Other survey techniques employing the voting and taxation approaches have been employed for non-environmental goods and services (Clark 1971, Tullock and Tideman 1976, and Smith 1977). A problem with many of these approaches for use in visibility benefit analysis is lack of credibility of the proposed situation as a method to actually determine air quality levels. These approaches may have all the problems mentioned for bidding methods and perhaps others associated with the often complex instructions and payment schemes involved.

Not all voting analyses need be based on hypothetical surveys. In real world situations, voting results may yield informative data in optimal quantities and WTP. In these situations voters choose to vote either for or against a proposition or to vote for one of two candidates with perhaps different views. These votes represent actual revelations of perferences just as market data reveal actual expenditures. The value of voting information depends critically upon how candidate positions and referendums are worded and how costs are to be paid by voters.

To be useful it must be assumed that successful referendums or candidates represent positions reflecting those of the median voter to insure the likelihood of gaining a majority position. Next, if the outcome of elections or referendums on the same issue can be simultaneously observed from many different political jurisdictions along with the differences in the propositions, outcomes, payment schemes, and socioeconomic characteristics of the voters, then statistical analysis can determine the demand for the good in question (see Freeman 1979a for discussion and application references).

Two problems are inherent in this analysis of actual votes. First, votes do not reflect intensity of preferences or of WTP. The same 51/49 percent split in votes can correspond to many different aggregate WTP amounts for the project (sum of benefits minus sum of damages) depending upon the socioeconomic characteristics of the supporters and opponents of the legislation. It may even be the case that many projects accepted (rejected) using a majority rule criterion would have been rejected (accepted) using a WTP criterion of comparing benefits to damages. Second, as Freeman (1979a) points out:

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[22] See Freeman (1979a) for a review of voting procedures. Suggested initial reading on demand revealing processes include Smith (1977), Clark (1971) and Tideman and Tullock (1976).

> The approach appears to be of limited applicability to environmental services and the benefits of pollution control in particular. The voting procedures of this and the preceding sections require that the choice of a quantity, a referendum, or a platform be coupled somehow with an obligation to share in some way in the cost of providing that public good. Therefore, these procedures would be capable of generating information on the demand for pollution control only in those cases where the costs of pollution control will be financed from revenues raised within the political jurisdiction.
>
> Many of the important pollution control problems for which benefit data are desired do not fit this description, at least in the United States. If some portion of pollution control costs is borne by the private sector, then the link between a vote on quantity and tax share or price is broken. And the vote cannot be interpreted as revealing anything about the economic demand for pollution control. Also, the voting approach would only be applicable where both the benefits and costs of the pollution control program fall entirely within the applicable political jurisdiction. If pollution spills across jurisdictional boundaries, some of the benefits of pollution control will be realized outside the jurisdiction. No voting measure could capture these interjurisdictional spillovers. (Page 104.)

4.5 Can Benefit Measures Be Transferred Across Studies?

It would be desirable to determine if the results from previous studies could be transferred to the problem at hand before undergoing the considerable expense and effort of performing a visibility benefit analysis. Two levels of accuracy are possible in transferring results. First, it may be possible in some cases to transfer actual or systematically adjusted results from past efforts to achieve reasonably precise benefit estimates for the current study, a level of accuracy we call strong transferability. Second, it may be possible to use previous results to set only ballpark upper or lower bounds on benefit estimates for the current study as a starting point for decision making, a level of accuracy we call weak transferability. Theoretically, conditions can be established which should insure valid strong or weak transferability of results. Whether these conditions are met is an empirical question for which there is very limited data at present.

Both cases refer to the ability either to transfer the estimated per capita benefits for a specific change in visibility and aggregating to total benefits or to transfer the estimated relationship between benefits for individuals and various levels of visibility or changes in visibility. This relationship is represented by the benefit function, such as the WTP or bid function estimated from a property value study or a bidding method surveys, which gives WTP or bids for visibility or changes in visibility as a function of the level of visibility or changes in visibility, socioeconomic characteristics of the population, and physical characteristics of the study area. Using these relationships, total benefits could be estimated by deriving estimates of individuals' benefits for the expected change in visibility in the current study area by adjusting the previously estimated benefit function and appropriately aggregating across all individuals expected to be affected by the change.

Strong tranferability requires either one of two broad conditions to be met. First, all population characteristics, current and proposed air quality levels and types of impacts, affected vistas, and land use characteristics must be identical across both sites. In this circumstance either site would be expected to yield the same benefit estimates. The alternative condition is that the two study areas are identical except for definable differences and that accurate and defensible benefit measure adjustments could be made to reflect these differences. For example, the residents of one metropolitan community may differ from those of another metropolitan community previously studied only in terms of incomes and the distances of their residences from the central business district. If the impact upon benefit measures of these differences is well known through repeated empirical verification, the previous study results could easily and accurately be adjusted and transferred.

Differences in tastes and preferences of the affected populations may be the most difficult to account for in transferring benefit measures. Perhaps the easterner who migrated to the west is willing to pay more for blue sky and clear views than the neighbor left behind. Perhaps the vacationer in a national park has different preferences for clean air than the nearby rancher. Willingness to pay for various aspects of air quality must be known for all of these different types of people before results from one area can be strongly transfered to estimate the benefits of an air quality change for a different population.

Another requirement for strong transferability is that the differences in population and site characteristics across studies be such that benefit functions need not be extrapolated beyond the values over which they have been estimated. The functional form of bid functions or WTP function may not be appropriate for data values outside the range for which they were originally estimated. To extrapolate beyond this range may result in substantial error in the benefit estimates.

Strong transferability requires the completion of a large number of benefit assessment studies to determine with confidence how differences in people and air quality affect benefit measures. Also, it requires the availability of a large number of complete studies from which to choose.

It would be unlikely to find completely homogeneous conditions across two study situations where all relevant variables can be measured and have the same influence upon the benefit analysis. Until more studies are completed, it will be difficult even to adjust benefit measures to achieve precise per capita estimates for a new situation. However, it may be possible to effect a weak transfer of results to establish either an upper or lower bound on per capita benefits. Suppose the current situation is nearly identical to a prior study except that the average income of affected individuals is greater and the proposed improvement in air quality is very similar but larger. Both of these changes are known to have positive effects on benefit measures. Consequently, the prior results could be used to establish a lower bound on the benefits. If these benefits far exceed the costs of the improvement, no further estimate of benefits may be necessary. On the other hand, an upper bound might just as easily be established, and if the upper bound is considerably less than costs, again no further research may be required.

The necessary conditions for weak transferability of results are that the individual's tastes and preferences can be assumed to be similar; that the direction, but not the magnitude, of the effect on benefit measures of the difference in the situations is empirically established; and that the differences, which will have substantial impact on benefit measures, can be identified. A serious limitation is where some differences will increase benefits and some differences will decrease benefits. Weak transferability cannot be established without estimates of the magnitude of enough of these impacts to ensure that the benefit measures are either an upper or lower bound for the new situation.

CHAPTER 5

VISIBILITY BENEFIT ASSESSMENT GUIDELINES

5.1 Purpose of the Guidelines

This chapter summarizes the various research tasks necessary in a typical visibility benefit assessment. For several reasons these guidelines are not intended to establish formal procedures that should or must be followed. First, at present there is no formal legislative requirement to perform visibility benefit assessments for which such a procedure would be required. Second, the guidelines should remain flexible to incorporate what is learned through more research and repeated application.

These guidelines will help the researcher understand the step-by-step procedures usually necessary to perform a visibility benefit analysis. The steps discussed in the rest of this chapter are shown on Figure 5-1. Steps 3 and 4, selecting the appropriate methodology and applying it to obtain visibility benefit measures, have been the focus of this guidebook. The remaining steps, many of which do not require economic analyses as such, are included in the guidelines as an indication of what is required to perform a complete benefit analysis and to incorporate the benefit measures into a benefit-cost framework for resource planning. This discussion is meant to be a fairly brief outline and will refer to more detailed discussions in other chapters as necessary. Where possible, these guidelines also provide relevant sources of data and information.

5.2 Guidelines

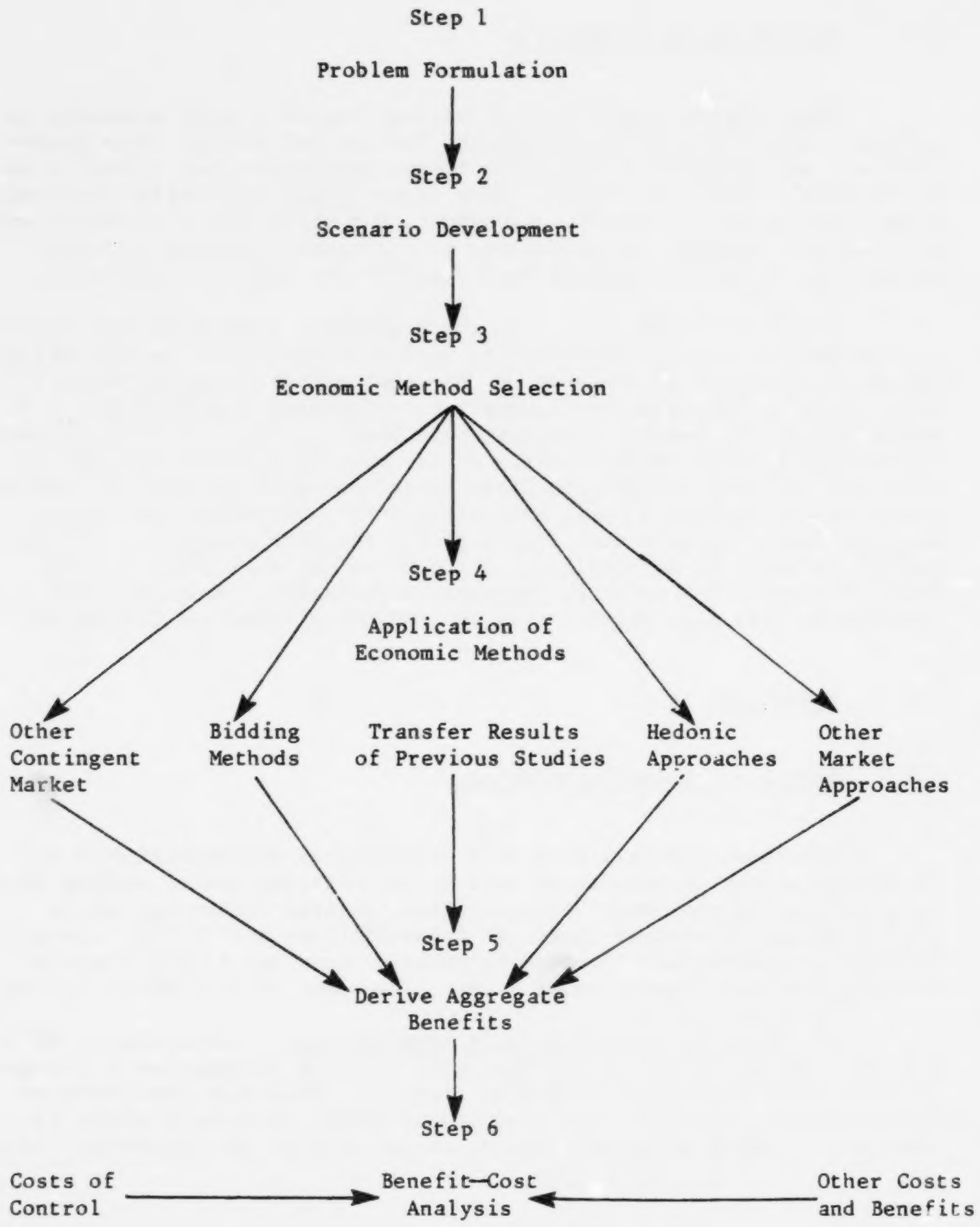
5.2.1 Step 1 - Problem Formulation

The first analysis step is a nontechnical determination of the nature and source of impacts as well as any existing public concern which could affect the analysis. At this stage, initial screenings can be used to determine whether technical investigations and further expenditure of funds are warranted. Problem formulation involves identifying and defining the basic issues under study. The steps in this phase include:

1. Describe the potentially impacted area. Specifically, define and describe the area or areas that will or could be impacted by changes in visibility conditions, including location, population (residents or recreationists or both), degree of urbanization, land use characteristics, etc. Impact areas may include one or more of the following: man-

FIGURE 5.1

VISIBILITY BENEFIT ASSESSMENT GUIDELINES


Step 1
Problem Formulation
Step 2
Scenario Development
Step 3
Economic Method Selection
Step 4
Application of Economic Methods
Other Contingent Market
Bidding Methods
Transfer Results of Previous Studies
Hedonic Approaches
Other Market Approaches
Step 5
Derive Aggregate Benefits
Step 6
Costs of Control
Benefit-Cost Analysis
Other Costs and Benefits

datory Class I Federal areas, other parks and recreation areas, Indian reservations, integral vistas from scenic outlooks, all or parts of urban areas, nonurban areas, or complete regions of the country (such as the Four Corners region, the Great Lakes region, the Golden Circle of National Parks, the South Coast Air Basin and the like).

2. Identify sources. Identify sources which will or could be responsible for changes in visibility levels at impact locations and the rates of emissions. These typically include urban plumes, power plants, smelting operations, burning of forest products, agricultural activities, natural hazes and dusts, construction activities and the like.

3. Define pollution changes. This includes the types and concentrations of pollution changes that will or could occur, with what pollutants, and the potential impacts. Improvements or degradations, plume blight or haze, and fugitive dust are examples of this type of change. Typical pollutants of concern include SO_2, NO_x, CO, TSP and ozone. Impacts may include reduction in visual range, discoloration, and health impacts, as well as agricultural and material damages. The potential intensity, duration, frequency and timing of impacts should also be identified.

4. Identify legal foundations. Identify any legal foundations and requirements relevant to the pollutant type, source and impact areas. These are identified for several reasons. Many types of pollution impacts are illegal, regardless of the costs or benefits of control, while other types and levels of impacts are to be allowed only if costs of control exceed benefits (see Chapter 1). Other regulations dictate the type of impacts that, at a minimum, must be examined and how benefits should be analyzed. Consideration of the relevant legal reqirements will assist the analyst to define the need for benefit analysis and to meet any analysis requirements. These may include the Clean Air Act and promulgated regulations, Prevention of Significant Deterioration (PSD) programs, state implementation plans (SIPs) and National Environmental Protection Act (NEPA) regulations.

5. Determine public perceptions. Public attitudes and perceptions concerning actual and potential emission rates and air quality levels must be determined through literature research or on-site investigation. This is helpful in defining the aspects of the problem that are considered important by those who are or will be affected and assists in identifying any related special issues of public concern.

6. Determine if further analysis is required. Projects whose "worst case" visibility impacts could easily be determined to be insignificant in terms of physical variables do not require further visibility benefit analysis. This can be done using SAI/EPA (1980) physical screening procedures based upon location of impacts; distance to receptors; and emission rates per day of particulates, NO_x and SO_2. Individual sources which do not exceed critical levels established by these screening criteria will not alter visibility conditions in a humanly detectable manner. If an impact cannot be humanly detected through observable reductions in visual

range, increased discoloration, or other measures of visual quality, there are no visual aesthetic benefits or damages to be measured and further visibility benefit analysis would be unwarranted (although analysis of health related or materials related benefits may be desired), because control of visibility impacts at this level is not required by clean air legislation. The exception would be if in Task 5 some specific public concern related to increased emissions were identified and merited separate consideration.

5.2.2 Step 2 - Scenario Development

If visibility benefit analyses are to be undertaken, it is at this stage that exact visibility scenarios should be developed for existing conditions, the future without the proposed change, and alternative futures with proposed changes in visibility conditions. This process serves to define precisely the alternative levels of impacts to be evaluated. It is also necessary to develop more exact technical relationships and impact definitions to link changes in emission rates to changes in visibility conditions using source-impact dispersion modeling as a means of linking costs of control to the estimated benefit measures. The impact definition formulated here will influence the selection of the economic valuation methodology.

1. Establish existing air quality conditions. These include visual range reduction using measures of visual range, light extinction, or green contrast; discoloration using blue-red ratio, intensity or concentration of pollutants; frequency, duration and timing; and types of pollutants and sources. Existing conditions may be obtained from airports or the National Oceanic and Atmospheric Administration (NOAA), urban monitoring facilities often operated by state air pollution control agencies, and monitoring facilities operated at and around several mandatory Class I Federal areas by or for EPA, EPRI and private organizations. (See Chapter 3 and EPA 1979.) It is also necessary to establish which of these air pollution impacts are perceiveable by humans, how they are perceived, and what the important visual aesthetic characteristics of the obstructed views are. Dispersion modeling, as suggested in Task 4 below, is required to establish the links between emission rates and air quality levels.

2. "Future without" scenario. Establish the most probable future conditions without the proposed change, if any change is expected, in the same manner as for existing conditions. Defining the expected future conditions without the proposed change establishes the appropriate baseline against which to compare and evaluate the impacts of proposed changes through time.

3. "Future with" scenario. Establish the conditions for one or more future scenarios in the same manner as for existing conditions. Precisely define proposed changes in visibility conditions to be evaluated.

4. Conduct initial physical impact analysis. The level 2 and level 3 analysis suggested by SAI/EPA (1980) could be used to perform more detailed impact analysis for physical parameters. This analysis can account for locations, atmospheric conditions, timing, topographic effects of plume transport and diffusion, and the effects on the scenic beauty of the area. Dispersion models for plume analyses, such as PLUVUE, have been developed by EPA/SAI (1980); ERT, Inc. (Drivas et al. 1980) and Radian Corporation (Fabrick et al. 1980). At present only the PLUVUE model has received limited validation as part of the EPA VISTTA program; however, the other models are generally very similar. Regional haze and long distance transport of emissions models are even less well developed. Recent research is also reported in the EPA (1979) and Chapter 3. Since this step is outside the realm of economics, it requires coordination with atmospheric/meteorology researchers.

5.2.3 Step 3 - Selecting the Approach to Estimating Economic Benefits

Once enough information has been gathered about the air quality impact to define the problem and develop alternative impact scenarios, the approach to estimating economic benefits of visibility can be selected. The first issue that should be addressed is whether results from previous studies can be transferred to the current benefit analysis problem at a level of accuracy sufficient for decision making. Transferring results will save considerable time and expense in performing benefit analyses, but this involves meeting several requirements. At present, many more benefit studies are needed before there will be a sufficient set of studies to be able to transfer results from them to new problems on a regular basis. Yet when results can be either strongly transferred to yield precise benefit estimates, or weakly transferred to establish that costs are either substantially larger or smaller than benefits, performing new benefit studies will not be required. (See Section 4.6.)

When prior results cannot be transferred satisfactorily to the current problem or when the analyst desires to validate these results, a benefit estimation study must be undertaken. In some instances the analyst may desire to apply more than one technique as a means of substantiating results.

Because each study problem will have unique features, the appropriate technique must be selected on a case-by-case basis. This section outlines several important criteria that should be considered when making this selection, and provides general indications about which technique is appropriate in which circumstances. The most important considerations will be the location and the nature of the impact to be evaluated. Other considerations include data requirements, necessary assumptions, costs, and timing requirements. Emphasis is placed here on bidding methods and the hedonic property value approach, since these are the primary techniques that have been applied in visibility benefit analysis. Many of the selection criteria also apply to other actual market and contingent market

Table 5.1

Selection of Visibility Benefit Estimation Method -- A Summary[1]

Selection Criteria	Transfer Results of Previous Studies	Bidding Methods and Other Survey Approaches	Property Values and Other Market Approaches
Major strength	Lowest cost, quickest results	Flexibility in application to location, type of impact and values	Reliability of data reflecting actual behavior
Major weakness	Lack of prior studies and consistent empirical analysis	Reliability of data from hypothetical questions	Availability of data for nonurban locations and required variations in impacts
Cost and timing	Lowest cost, quickest results	Highest costs, often takes > 1 year, seasonal problems	Medium costs, usually < 1 year
Locations where impacts can be addressed	At present: weak transferability for urban areas and Southwest parks	All locations, Class I, urban, rural, other	Urban, or where sufficient data exists
Types of values	Constrained by prior studies, primarily activity values	Activity, option, existence	Activity, some option
Separability of impacts (health vs. aesthetics, etc.)	Constrained by prior studies, primarily not separated	Benefits are separable	Separability not yet addressed
Types of impacts that can be addressed	Constrained by prior studies	Haze or plume, and rates and levels of occurence; uniform or variable	Haze or plume, and rates and levels of occurence; must vary across study area
Evaluation of current vs. future impacts	Both, depending upon prior studies	May evaluate both current or future impacts	All alternative impact levels should occur in study area
Atmospheric data requirements	Accurate data required to match current situation to prior studies	Accurate data required for alternative "typical situations" across area	Accurate data required on all pollution levels at a neighborhood or census tract level
Economic and population data	Affected population characteristics	Affected population characteristics must be cross-checked with sample characteristics	Property values, property use and characteristics plus population characteristics
Reliability of data and results	Depends upon accuracy of prior studies and match to current impacts	Some uncertainty due to hypothetical approach	Reliable market data, some uncertainty regarding estimation techniques
Assumptions	See Table 5.2.		

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[1] This table is to be used only as a summary of more detailed comparisons contained in Chapters 4 and 5 of this guidebook. The same criterion can be applied to travel costs, wage and salary hedonic techniques, etc., as they are developed for application to visibility benefit analysis.

approaches, such as travel cost approaches, and wages and salary analysis. In general, bidding methods and other contingent market approaches are more flexible than the hedonic approaches, but when the hedonic approaches can be applied the data are often more reliable. However, a violation of the key assumptions behind either technique may render it inapplicable.

The following are some of the criteria that should be considered in selecting the appropriate benefit estimation technique. These selection criteria are summarized in Table 5.1.

1. Location of the impact. Bidding methods can be applied to estimate benefits of visibility changes in all locations, including urban, rural, and Class I areas. Property value studies and other actual market approaches can be used only in urban areas or in highly developed recreation areas or nonurban areas where property or wage and salary markets are extensive enough to generate the necessary data. Bidding methods, other contingent market approaches, and variants of the travel cost approach are probably the logical choice for estimating air quality benefits in most recreational, wilderness, and sparsely populated areas. The hedonic technique applied to residential property values will pick up only impacts at the home site, while bidding methods can pick up air quality impacts that occur at residential, recreation and work sites.

2. The nature of the impact. The nature of the air quality impact will be determined by several different aspects of the problem. The following are some of the types of impacts that need to be considered when selecting an air quality benefit estimation technique.

Current or future impacts. Bidding methods can be used to evaluate alternative visibility scenarios which are currently being encountered or which are expected to be encountered in the future, although the future scenarios will be hypothetical to the respondent unless he has experienced it elsewhere. Property value studies can capture the valuation for alternative visibility scenarios that have been or are currently experienced in some portion of the study area. Scenarios of visibility levels that have not occurred could be evaluated with the hedonic approach only by transferring results from other locations or by using local data and extrapolating the estimated WTP functions to the proposed visibility level.

Impacts from haze or plume. All methods can address both haze and plume visibility impacts of air quality changes as long as the impact affects the individuals' behavior being analyzed. This may be a problem where there are uniform impacts across individuals. For example, an urban plume or haze may uniformly obstruct a prominent local view or degrade air quality equally for all households in a community. Property value differences within the community would not usually reflect the benefits of controlling these problems, unless changes in air quality over time were reflected in property values and this data were obtainable.

Frequency, intensity, and duration of impacts. Bidding methods and other contingent market approaches could conceivably test for the effects of variations in the frequency, intensity, and duration of the air quality impacts, but the techniques are constrained by the respondent's limited capacity or desire to absorb information and differentiate among alternatives. Hedonic techniques could test for the effects of different frequencies of certain air quality levels if the available data are sufficiently detailed and accurate.

Aesthetic, health, or materials impacts. These three air pollution impacts often occur together and are often highly correlated. In many instances it will be difficult to separate benefit measures for the separate impacts. With careful survey control and impact definition, the economic effects of these different air quality impacts can be separated in the bidding and other contingent market approaches. This separation will be difficult with hedonic property value approaches unless measures reflecting the different impacts are not highly correlated with one another. Such measures are, however, frequently correlated because many pollution causing activities, such as burning of fossil fuels, produce several different kinds of pollutants that each have different kinds of impacts.

3. Type of value for which benefits are to be estimated. Complete benefit estimates would include activity, option and existence values, but depending on the goals of the current study the researcher may choose to examine only one or two of these values. If impacts are at a national park, activity values must be determined for users of the park. Option and existence values must be estimated by obtaining benefits for users and non-users. Benefit estimates for non-users cannot be obtained on-site and will often rule out most actual market and travel cost approaches. The same problem also occurs for existence values in urban areas. Bidding methods can be used to estimate each of these types of values. Other contingent market approaches can capture activity values, while their ability to capture option and existence values has yet to be demonstrated. Hedonic techniques can capture the activity value of air quality at the property and work sites, and to some extent the option value of the current air quality level, although separating these would be difficult. Existence values probably do not affect property values or wages and salaries, and therefore are not captured by the hedonic technique.

4. Data requirements and reliability. These include both secondary data obtained from outside sources and primary data generated by the current study. For example:

Atmospheric data. All approaches to benefit-cost analysis require that emission rates be accurately linked to visibility and other air quality measures used in the analysis and that indivduals sense the differences in air quality conditions. In this way the correspondence between benefits and costs for proposed changes can be maintained. The hedonic approach further requires accurate estimation of all potentially relevant current air quality measures at the neighborhood or census tract level. Survey approaches require that selected typical levels of air quality can be tied to emission rates and related to respondents in a manner they can understand and accurately respond to.

Economic and population data. The survey methods require accurate economic and population data to establish survey sampling procedures, to check survey response rates, and to aggregate individual valuations to totals for the impacted population. This is sometimes a problem in non-urban or recreation areas. The hedonic technique requires extensive property use and characteristics data as well as household and neighborhood characteristics data for the entire study area.

Data reliability. The bidding methods generate primary data on an individual's willingness to pay for various levels and aspects of air quality; however, these data are subject to potentially substantial inaccuracies due to the hypothetical nature of the questions, and due to potential strategic and information biases. Reliable secondary data for the hedonic approach are usually available in urban areas, but special procedures and assumptions may be required to make data from various sources compatible and applicable for the estimation technique.

5. Necessary assumptions. Assumptions used in benefit estimation techniques can be categorized as to whether they are analytical--used in the theoretical development--or operational--used in application of the procedures. Table 5.2 presents a summary of assumptions used for three representative techniques; property value studies, bidding methods and the contingent travel cost approach. If the assumptions used in any technique are not valid in theory or not met in practice the validity of the results generated by the technique are weakened.

To transfer results from previous studies it is first required that the previous study technique and results be defensible. Next, it must be assumed, or hypothesized, that the individuals, assumptions, and circumstances are identical across the two studies or are different in definable ways and that the range of visual quality for which the benefit measures have been determined is comparable to the range of visual quality currently under study.

6. Costs and timing requirements. The costs and amount of time required to perform a benefit analysis may significantly affect the choice of estimation approaches. Many efforts will be comparable across approaches, including model design and initial data analysis. Efforts to obtain and enter data may vary significantly.

Survey methods require a survey instrument and sampling procedure design, survey pretests and evaluation, interview training, and an on-site survey effort. Costs will vary dramatically depending upon location of the interview site, availability of trained labor, time limitations, and the length and type of interviews undertaken. One hundred or more completed interviews using a cluster sample can easily vary from $10,000 to $50,000 and take from one month to one year just to complete the survey design to final data receipt tasks. In order to obtain an adequate sample of users, survey methods may also have to wait until a peak use period in recreation areas.

Table 5.2

ASSUMPTIONS IN VISIBILITY BENEFIT ESTIMATION

Assumptions	Estimation Technique Property Value	 Bidding Method	 Contingent Travel Cost
I. ANALYTICAL ASSUMPTIONS			
1. Consumers make choices to maximize utility subject to budget constraints. Utility functions are regularly shaped; directly or indirectly increasing in visibility, all goods, all activities and income. All individuals have the same utility function or are different in definable and measureable ways (education, age, ethnic background, etc.). Income is assumed to be constant.	X	X	X
2. Only air quality environmental changes occur (no changes in water quality, congestion, etc.).	X	X	X
3. Air quality changes have the following impacts upon prices.			
a. Changes in air quality do not affect any prices.		X	X
b. Changes in air quality affect only property prices.	X		
4. Air quality changes have the following impacts upon rates of activities and expenditures.			
a. Activities and expenditures do not change with changes in air quality.		X	
b. All activities and expenditures may change.			X
c. Only housing activity and expenditures change.	X		
5. Households purchase one unit of property or, if more than one, all are identical.	X		
6. Property markets are pervasive, have no imperfections and are in equilibrium so as to reveal utility maximizing choices.	X		
II. OPERATIONAL ASSUMPTIONS			
1. Technical measures of air quality or pollution that are used by researchers accurately reflect those aspects of visibility impairment to which individuals react in the given situation.	X	X	X
2. Visual presentation of air quality conditions accurately communicate those attributes of air quality to which individuals react in the given situation, and are accurately correlated to technical measures.		X	X
3. Realistic hypothetical market situations can be described by the researcher and understood by the respondents, and, respondents are capable and willing to accurately predict their behavior in the described situations.		X	X
4. Individuals are not biased by the questionnaire procedure or, if they are, these biases can be detected and correctly accounted for in the analysis.		X	X
5. Consumers have mobility and full information on alternatives and are unconstrained in making choices.	X		X
6. Weak separability in the utility function is assumed so that only related expenditures and activities need to be examined.			X
7. Weak separability in the utility function is often assumed so other types of averting behavior and expenditures need not be examined (this parallels analytic assumptions 3b and 4c).	X		
8. The urban area as a whole can be treated as a single market without imperfections, or the imperfections can be accounted for.	X		
9. A random sample of individuals representing a cross-section of those affected can be drawn.		X	X
10. A random sample of properties can be drawn, which exhibit a continuous variation over an adequate range of the air pollution measure and property characteristics to perform statistical analysis.	X		
11. Appropriate function forms can be specified for analysis.			
a. Bid functions or WTP functions can be specified which correctly reflect underlying utility functions.	X	X	X
b. The correct hedonic price function can be specified and the correct form is nonlinear.	X		
12. All influences which affect the valuation process can be determined and accurately quantified.			
a. This includes air quality; population, housing, and neighborhood characteristics.	X		
b. This includes air quality and population characteristics.		X	
c. This includes air quality, rates of activities, expenditures, and population characteristics; and the value of travel time and costs.			X

The costs of the hedonic approach will depend upon the difficulty of gathering the necessary data. In most urban areas market research or census data tapes may be quickly obtained for a few hundred to a few thousand dollars. Other local data are often immediately available from local government agencies. If additional data are needed, primary surveys or hiring professional real estate appraisors will considerably increase expenses. The costs of obtaining and organizing the necessary secondary data for hedonic approaches will typically be less than one-third those of a survey effort. This will depend in part upon the effort required to get the data running on the local computer. The time frame of the data will affect the validity of the hedonic approach, but the implementation of the study will not be constrained by the same sort of seasonal problems that can afflict the survey approach; therefore, the hedonic approach can usually be more quickly implemented. Due to the complexities of this approach, the modeling and data analysis costs are substantially larger than for the bidding method approach.

5.2.4 Step 4 - Application of Economic Methods

This section focuses upon the bidding method and property value approach to benefit estimation because these are the two approaches most thoroughly developed and commonly used to date.

5.2.4.1 Application of Bidding Methods

In applying the bidding methods, it is neccessary to design the appropriate benefit estimation model, to finalize the selection of alternative scenarios to be evaluated, and to determine how they will be presented to respondents. This process can be as follows:

1. Selection of benefit measures. At this stage, it is appropriate to determine the benefit measures the survey will attempt to estimate from the WTPB, WTPG, WTAB, and WTAG approaches. Property right structures must also be considered.

2. Select alternative scenarios to be evaluated. Usually no more than four alternatives should be presented to respondents.

3. Select the methodology for depicting the visibility conditions. Typical approaches include regular photography, overlay techniques, retouch techniques, artist renderings and computer simulated techniques. Regular photography is the predominant approach for depicting visibility conditions. The standard application is to use a 35mm camera with a 135mm lens, which gives a precise one-for-one image, and Kodak-chrome II film with film speed of ASA25 and typical exposure of F8 at 1/125 second, processed in batch at Kodak labs. The pictures are usually 1/3 - 2/3 split between sky and land to give foreground, middleground and distance features as well as sky conditions. The direction of the scenes and time of day are important

considerations because of the influence of backlighting. No-cloud scenarios are becoming standard because the measurement of visibility conditions is more accurate under this condition. Further references can be found in Chapter 3, Ettenheim (1979), and EPA (1980). The EPA is also currently developing a twice-a-day historical photo file at several mandatory Class I Federal areas.

Computer simulation and other techniques are used when the proposed alternative conditions do not or have not existed, or simply cannot be captured with regular photography. This technique has been developed and used by Williams et al. (1979) at Los Alamos Scientific Laboratory. Several scenes are frequently used, depicting typical vistas and special landmarks potentially impacted by visibility changes.

4. Determine survey procedures. This must take into consideration which impacted populations are to be surveyed, where and how they are to be surveyed, sampling procedures and the design of the survey instruments. As previously discussed, personal interviews and guided interviews are typical methods. Survey procedures in recreation areas are discussed in Section 4.2, Brookshire et al. (1976) and Rowe et al. (1980). Examples of survey procedures in urban areas can be found in Brookshire et al. (1979), EPA (1981) and recent NPS/EPA/Wyoming work to be released.

5. Design the survey instrument. This is the most critical stage for successful application of a bidding method or contingent market approach. It is discussed in detail in Section 4.2.

6. Pretest. All survey instruments and procedures should be pretested in the manner and at the site for which they are designed. The procedure and the instrument are then redesigned based upon pretest evaluations.

7. Implement the survey. The survey should be implemented as designed to a sample of sufficient size to make the necessary statistical inferences with the desired degree of precision. (The appropriate sample size is best determined from the pretest.) Samples of 100 or more for each major group (recreationists, residents at each separate location, etc.) are usually required. See Section 4.2.

8. Analyze survey results. At this stage, standard analysis of mean, variance, correlation, cross-tabulation, and regression analysis of the bids and socioeconomic variables and other data are conducted. Bid functions relating individual bids to visibility levels, socioeconomic variables and other study variables may also be estimated. Several alternative functional forms must be estimated to test the robustness of the estimated impacts of variables upon reported bids. Mean values by classification scheme (income levels, urban, non-urban, etc.) and/or bid functions should be developed for each potential change in scenarios for each value type (activity, option, existence) estimated for each affected population group. Finally, tests and verification of the survey procedure and instrument biases may be carried out and other special questions evaluated (for details see Section 4.2).

5.2.4.2 Application of Hedonic Approaches

The application of the hedonic approach encompasses three major steps beyond the determination of impacted populations and data availability: the first is final data selection, the second is data organization, and the third is statistical analysis.

1. Select final data. The two most important data selection decisions are which property value and air pollution data to use. Care must also be taken to ensure that all the important amenities that influence residential location decisions in the study area have been identified.

Select property value data. Household-level data are sometimes available from market research firms, real estate or financial organizations, or local government. Household-level data are preferable if enough house structure and household socioeconomic data are also available at the household level. Examples of typical data needed were given in Table 4.4. If adequate household-level data are not available the analyst must decide whether to use U.S. Census data, which will be available for any urban area; aggregate data from other sources, such as local government, for census tracts or other small divisions of the study area; or whether to have professional property value assessments done in the study area. The latter choice will be considerably more expensive and may be worthwhile only if equally reliable house structure and household-level socioeconomic data can be obtained. Many studies have settled for the census data, which provide census tract averages of property value, house structure and household socioeconomic characteristics. Census tracts are selected to be as homogeneous as possible, but some information is inevitably lost in the aggregation.

Select air pollution data. Most property value studies have used measures of pollutant concentrations to represent air quality. These have the advantages of being readily available for most urban areas and of being reasonably well linked to emission sources. However, pollutant concentration measures may not be entirely adequate for visibility benefit analysis because visual impacts are often caused by combinations of pollutants or by some components of the measured pollutants. For example, Heisler et al. (1980) found that only the smaller particles that make up about half the measured TSP contribute significantly to the visible haze in the Denver area. Alternatively, direct data on aesthetic impacts such as visual range and discoloration are not as readily available and the links between such measures and emission sources are less well known. Future research on this subject may eventually lead to availability of measures of aesthetic impacts that are adequate for property value studies.

Which measure of air quality to use will depend on which pollutants are most prevalent in the study area and which of these are responsible for perceived impacts. If available, several measures should be used to check for consistency and to determine the best proxy for the impact being studied. Usually only one air quality measure can be used in a hedonic price function due to the typical correlation between measures. There are not usually air quality monitoring stations in every census tract or even in every neighborhood in an area, therefore, air quality measures for each neighborhood must be extrapolated from monitoring station data. This is often done using isopleth maps developed by local air quality surveillance agencies that trace typical air patterns over an area. Some air pollution dispersion models are also available though these are still in developmental stages.

Verify important neighborhood amenities. This will improve the reliability of the estimated influence of air quality on property values. On-site observation and/or a small survey of residents might bring to light overlooked amenities that are influencing property values. Appropriate data to represent all important neighborhood amenities must be obtained.

2. Organize data. Data from different sources must be made compatible, and a study sample of the impacted population must be selected. This can be done as follows:

Adjust data from different sources for compatibility. Even if census data are used, additional data must be obtained from other sources. Transportation, tax, public services, school, and employment data are available from local governments, although these are not always reported for the same area divisions. For example, school district boundaries and census tract boundaries do not usually coincide. These differences must be reconciled in some reasonable and consistent manner.

Select study sample. A sample must be selected from the impacted population to limit some of the non air quality differences between properties. Many studies have eliminated tracts with less than a certain percentage of owner-ocupied houses or more than a certain percentage of business properties. Others have used more sophisticated statistical analysis to group or pair neighborhoods or tracts to minimize differences except air quality. In smaller or less populated study areas this selection process will be constrained by the smaller number of property value observations. The sample must also be selected in accordance with standard sampling procedures to ensure that it is representative of the impacted population.

3. Perform statistical analysis. The next major step in the hedonic approach is the statistical analysis, which includes estimation of the hedonic price function, WTP functions and benefits or damages.

Estimate hedonic price function. First, the hedonic price function must be estimated using standard statistical procedures. Two particularly serious problem areas for the estimation of the hedonic price function are the question of whether market segmentation exists in the study area and the question of what is the appropriate functional form. These problems are discussed in detail in Section 4.3.2.

Estimate WTP. The current procedure for estimating willingness to pay for air quality is to take the marginal implicit price for air quality as an observation of the household's WTP, as described in Section 4.3.2. Demand determining household and property characteristics are used as explanatory variables. Household income is probably the most important characteristic, but other characteristics should be tested to ensure that welfare measures are not unstable across different specifications of the WTP function. Also, to assure that the WTP function is identified, some considerations must be made regarding the supply of residential site air quality.

Estimate benefits or damages of the changes in air quality. From the WTP function, the change in consumer surplus for each household or household group that will result from a change in air quality can be derived. Alternatively, rough estimates of the change in consumer surplus can be directly derived from the marginal implicit price function for air quality, as described in Section 4.3.2.

5.2.5 Step 5 - Aggregation of Benefits Across All Affected Populations

Each technique estimates benefits for a typical individual with certain characteristics for a precise unit of time. Examples include annual benefits to homeowners segmented by pollution level and income level, or daily benefits to typical recreators. The total society benefit is the aggregation of benefits to all affected individuals for as long as the impacts occur.

1. Aggregate across individuals. Bid curves, WTP functions or mean values by selected classifications are aggregated across all affected individuals for each value type (activity, option, existence) for each potential change in scenarios. Total benefits are usually estimated on a per year basis throughout the project lifetime. It may also be desirable to use the Water Resource Council's Principles and Standards approach (1979), which displays benefits and damages by categories of "region" and "rest of nation" and specifically separates impacts to low income, unemployed, or minority individuals to address equity issues of how costs and benefits are distributed.

2. Aggregate across time. Future benefits and damages are often discounted to present values so that all benefits may be aggregated to a single total benefit measure. Both the appropriate time horizon and discount rate must be selected. Discounting represents an intertemporal weighting of benefits for which there is substantial controversy as to the correct weighting scheme. Arguments range from using a zero rate of discount to a high rate of discount based upon public and private rates of return on investments, efficiency arguments, and other related issues (see Section 2.3). The discount rate used may be determined by legal requirements, as is the case for federal government projects; as a decision variable; or by using existing private market rates and time horizons. In most cases it will be beneficial to report aggregate benefits using several alternative rates to demonstrate the impact of selecting discount rates upon total benefit measures.

5.2.6 Step 6 - Benefit-Cost Analysis

Visibility benefits or damages, which have been the focus of this guidebook, are only part of the total benefits and costs associated with changes in the number or rate of operation of power plants, other industrial sources, prescribed burning and multiple source regional emissions. Any decision-making process for optimal resource allocation should take into account all costs of emission control associated with alternative visibility levels and all other environmental and non-environmental costs and benefits. The steps in this phase are as follows:

1. Identify emission control costs. Where possible, initial visibility scenarios should have been developed so that the related costs of emission control equipment can also be estimated.[1] Initial estimates for best available retrofit and control technologies for existing and new coal-fired power plants are available through the EPA (1980). The Bureau of Census also publishes an annual Pollution Abatement Costs and Expenditures. The costs of reducing non-industrial emissions, such as from prescribed burning, must also be considered. For example, the costs to timber land owners of using alternatives to burning, such as mechanical treatment of forest residue, should be considered an emission control costs.

2. Identify other environmental and non-environmental costs and benefits. In many cases the estimation of other related cost and benefits may be of substantial importance and may require even more efforts than for visibility benefit estimation. Changes in air quality will also have benefits in health, agricultural and materials damage categories. The importance of considering other benefits is demonstrated in a benefit-

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[1] A theoretically correct measure of the costs of emission controls would be the decrease in producer and consumer surpluses caused by the additional costs of producing the good affected by increased pollution control (electricity, automobiles, etc.) In most cases the change in the producer's total costs is taken as an approximation, the accuracy of which depends on the elasticisties of demand and supply of the good. (See Hirshleifer 1976.)

cost case study for New Haven, Connecticut, which found visibility aesthetic benefits to be up to five times larger than those from reducing acid rain, agricultural and materials damages; but on the average only one-seventh the magnitude of health-related benefits (Mendelsohn 1980). Other impacts that may have to be considered include the effects of higher energy costs, transportation costs, the social desirability of energy independence, land use impacts, and the like. A complete analysis may also consider secondary impacts. For example, increased visibility degradation in a national park would decrease the well-being of tourists and the rate of tourism. Consequently, local economic revenues would also be decreased. See NEPA regulations for typical multi-objective resource planning impact categories and methodology for ranking alternative projects; and see Mishan (1976), Sassone and Schaffer (1978), Abelson (1979), and Maler and Wyzga (1976) for discussion of benefit-cost analysis techniques.

CHAPTER 6

CASE STUDIES OF VISIBILITY BENEFIT ANALYSIS

This chapter discusses five visibility benefit studies in which the bidding method was used and five in which the hedonic property value approach was used. Although the bidding method has been applied in several dozen other environmental/resource problems in recent years, these five are the best known applications to visibility benefit estimation.[1] There have been nearly two dozen property value studies related to air quality and visibility.[2] The property value studies discussed here represent the most recent applications of the Rosen-Freeman theoretical framework, presented in Chapter 4, which is considered to be the most defensible framework to date.

These case studies are being presented to exemplify actual applications, typical results, and strengths and problems for each of these two approaches to assist researchers and policy makers in designing and evaluating potential new visibility benefit studies. The discussion for each case study follows, as much as possible, the guidelines presented in Chapter 3. Many of the studies, however, do not follow or perform each of the steps because they were the first attempts to test the economic techniques or to establish order-of-magnitude estimates of benefits or damages related to changes in air quality, and as such the researchers were not concerned with performing complete benefit-cost analyses.

6.1 Case Studies Using Bidding Methods

The studies examined here are the Four Corners study, by Randall et al. (1974); the Lake Powell study, by Brookshire et al. (1976); the Farmington study, by Rowe et al. (1980a,b); the South Coast Air Basin study, by Brookshire et al. (1979); and the Grand Canyon/Southwest Parks study, by EPA (1981). With the exception of the South Coast Air Basin study, all of these studies relate to visual range and discoloration impacts upon Class I areas and local communities in the southwestern United States induced by rapid growth in the coal-fired electric-generating industry. Each study examines at least one alternative level of impacts, but seldom are the impact scenarios and benefit measures linked to actual emission levels or control costs; nevertheless, the results exhibit a high degree of similarity across studies.

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[1] For a partial review of bidding method studies for a variety of applications compiled prior to mid-1979, see NUREG 1979.

[2] For a review of property value studies completed prior to 1979, see Freeman 1979a.

A tabular comparison of selected elements of bidding methods is provided in Section 6.2.7. Sample questionnaires and photographs are included in Appendix 1.

6.1.1 The Four Corners Study

The Four Corners study, as reported by Randall, Ives and Eastman (1974a,b), was the first in which a bidding method was used to assess the economic benefits and damages associated with changes in air quality and other environmental variables. As such, the study was more concerned with developing the technique and obtaining defensible order-of-magnitude damage estimates than with precise definitions and links between visibility conditions, emission rates and control costs, as would now be required for a visibility benefit-cost analysis. This study was part of a larger socioeconomic impact assessment of the rapidly expanding coal-fired electric-generating industry, including power plants and strip mines in the Four Corners region (southwestern United States) undertaken by New Mexico State University.

Problem Formulation and Scenario Development

The specific concern of this study was the Four Corners power plant in Fruitland, New Mexico, and the Navajo mine, which provided low-energy, low-sulfur, high-ash subbituminous coal. The 1970 power plant capacity was 2,080 MW. It was expected that some 31,000 acres would be stripped over the 40-year life of the mine and that 96,000 tons of particulates, 73,000 tons of sulfur oxides, and 66,000 tons of nitrous oxides would be emitted annually. The emissions had already considerably reduced local visibility from the natural state of around 160 km down to between 60 and 100 km (Kneese and Williams 1978).

The Four Corners region is sparsely populated and is typified by desert landscapes best enjoyed from long distances. At the time of the study (1972) there were no cities of over 50,000 inhabitants in the region; however, several large Indian reservations, including the Navajo reservation, and several national parks and monuments are in close proximity (see Figure 6-1). In subsequent years actual and proposed emissions in the Four Corners region became one of the driving forces behind the 1977 passage of the Clean Air Act.

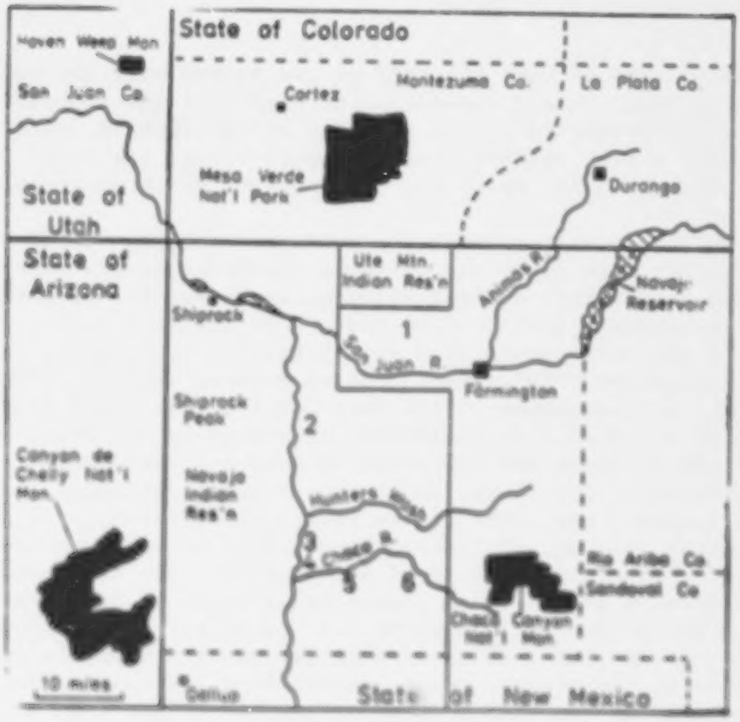
Hoven Weep Mon
San Juan Co
State of Colorado
Cortez
Montezuma Co.
La Plata Co
Mesa Verde Nat'l Park
Durango
State of Utah
State of Arizona
Ute Mtn. Indian Res'n
Animas R.
Navajo Reservoir
Shiprock
1
San Juan R.
Farmington
Shiprock Peak
2
Canyon de Chelly Nat'l Mon
Navajo Indian Res'n
Hunters Wash
3
4
Chaco R.
5
6
Rio Arriba Co
Sandoval Co
Chaco Canyon Nat'l Mon
10 miles
Gallup
State of New Mexico

Figure 6.1. 1978 existing and proposed coal-burning power plants in the Four Corners region of southwestern USA. Existing: 1 San Juan Power Plant (2,173 MW); 2 Four Corners Power Plant (660 MW and 1,000 MW). Proposed: 3 WESCO I; 4 WESCO II; 5 Burnum II; 6 Burnum I. (Source: Rowe et al. 1980b.)

Three scenarios of past and expected future levels of impact were developed and supported with photographic representations. Scenario A "showed the plant operations circa 1969, prior to installation of additional emission control equipment, producing the historical maximum emission of air pollutions." (Page 137.) Scenario B "showed an intermediate level of damage...showed the plant circa 1972, after additional controls had reduced particulate emissions (i.e., the type of emission most destructive of visibility)." (Page 137.) Scenario C "showed the plant with visible emissions reduced to zero." (Page 138.) The impacts of each scenario also included various degrees of reclamation of soil bank (A=unreclaimed, after strip-mining, B=leveled but not revegetated, and C=natural), visible transmission lines (A=highly visible, B=visible in distance, C=natural) and a visible power plant. The alternative scenarios were depicted with regular photography; however, the scenes and their contents were not standardized.

Application of the Bidding Method

Bidding methods were selected as the method with the most potential for estimating benefits and damages associated with the proposed changes in environmental conditions. The location of the impacts, much of which were on or over Indian reservations, national parks, state and Federal land and utility company land, ruled out the property value approaches.

A typical iterative bidding procedure was used. After an introduction, respondents were shown the pictures representing the alternative scenarios and asked their maximum willingness to pay for proposed improvements in environmental quality from state A to states B and C (WTP^G = CS measures). A few respondents were also presented willingness to accept compensation question (WTA^B = CS). Three payment vehicles were used. A sales tax on all purchases in the Four Corners Interstate Air Quality Control Region to finance environmental improvements and which would be required of all citizens was presented to some non-reservation residents. An electricity-bill vehicle was presented to other residents. In this case, the respondent was asked his current monthly electricity bill, then asked to imagine that an additional charge would be added to his electricity bill and to the electricity bills of everyone who used electricity produced in the Four Corners Region, even people as far away as Southern California (page 140). The monies would then be used to repair the environmental damages. A user fee for recreation services was presented to non-resident recreationists in the region, and a general fund for environmental protection was proposed on the Indian reservation. Zero bids were evaluated as described in Section 4.2.3. Standard socioeconomic questions were also asked. To capture valuations for the three predominantly affected populations, pretested personal interviews were completed for 526 residents, 71 on-reservation Indians and 150 non-resident recreators at several parks, monuments and forests in the region.

Analysis of Results

Randall et al. (1974a) reported the results for the sales tax approach used with residents. The mean sales tax bid for residents for an improvement from the worst to moderate conditions was $50 annually, and from worst to best conditions, $82.00 annually. The effect of higher incomes on bids was modest, as reported by income elasticities ranging from .39 to .63 for non-reservation residents. Income elasticities statistically equal to zero were reported for reservation residents and recreationists.

Few other results of the bidding procedure are reported in Randall et al. (1974). Apparently no tests for vehicle bias or other biases were conducted. Bid functions, which relate individuals' bids to visibility and socioeconomic characteristic, were not reported. Randall et al. (1974b) indicates protest bids as a percent of total bids ranging from 21% for utility bill payment vehicles to 32% for sales tax payment vehicles for local residents and up to 69% for residents of Indian reservations with WTP^G questions. Protest bids were given by 32% of the resident respondents and 4% of recreationists given WTA^B questions.

Aggregate Benefits Measures

A central component of this study was the aggregation of bids to derive a public goods bid curve which relates aggregate bids to visibility levels, as proposed by Bradford (1970). (See Section 2.4.4.) The results of the sales tax payment survey for residents were added to the user-fee payment survey for recreationists and aggregated to a total regional WTP. The results of the electricity bill payment approach were also aggregated separately for all consumers of Four Corners power. This second aggregation was not reported because the authors felt that "More faith may be placed in the regional bid since that bid was derived from all samples of all segments of its relevant population" (page 141), while the southern California consumers of Four Corners power were never surveyed.

Table 6-1 reports a summary of aggregate results from Randall et al. In summary, the authors state in a footnote:

> We are not yet in a position to present a complete benefit/cost analysis of the abatement of the aesthetic environmental damage associated with the Four Corners power plant and Navajo mine. Preliminary and tentative calculations indicate that, if our attribution of most of the benefits reported here to abatement of particulate air pollutants is reasonable, 99.7% abatement of particulate emissions (the current New Mexico standard for 1975) is economically justified on the basis of aesthetic considerations alone. Some additional abatement beyond the 1975 standard may be justified. The economic benefits from that abatement which has already taken place appear to far exceed the costs. (Page 145.)

Table 6.1: Aggregate Benefits For Abatement of Aesthetic Environmental Damagages Associated With the Four Corners Power Plant, 1972

Item	Situation A	 B	 C
Emission (tons of particulates per year)	96,000	26,000	0
Estimated regional aggregate bid ($ millions per year)	0	15.54	24.57
Standard error ($ millions per year)	-	1.24	1.52
95% Confidence limits ($ millions per year)	-	±2.43	±2.97

Evaluation Comments

This study was the first to show that bidding methods could be applied to estimating benefits and damages associated with changes in environmental quality. In addition, it further established a research agenda for years to follow.

The study has several weaknesses. Because the scenarios were not standardized and included impacts relating to visibility, soil bank reclamation, visible transmission lines, and visible power plant siting, the benefits/damages of each type of impact cannot be separately or accurately estimated. Next, the electricity bill payment vehicle lends itself to potential strategic bidding. If respondents had believed that all power users, including Californians, were to pay for improvement, from which all benefits would be derived locally, they may have bid higher to increase local benefits paid by non-local power users. Finally, an aggregate bid curve was estimated across the three levels of environmental impacts, but little confidence can be placed in estimation procedures based upon three data points.

6.1.2 The Lake Powell Study

The Lake Powell study, as reported by Brookshire, Ives and Schulze (1976), was undertaken as part of the NSF-RANN Lake Powell Research Project conducted at the University of New Mexico.

Problem Formulation and Scenario Development

At the time the study was initiated (1974) the 2,400 MW Navajo coal-fired electric-generating power plant was being built overlooking Lake Powell, and several other large power plants were being proposed for the area. The Navajo plant was to be fully operational in 1976. The Kaiparowitz power plant, which received so much attention in the early 70's, was to be located just to the north of Lake Powell and was to be even larger than the Navajo plant.

The Navajo power plant was expected to have significant environmental impacts. The potential of another large plant was of great concern to environmentalists and local residents. (An example of a typical Navajo plant plume as viewed from the neighboring community of Paige, Arizona, in 1979 is shown on Figure 1-6 of the EPA Report to Congress, 1979.) The study concerned itself with the "disturbing visual impact of large power plants with 700 ft. stacks in a predominantly natural recreational setting... (and) ... the smoke plumes and resultant loss of visibility, which may obscure the view." (Page 326.) The Lake Powell region has very few residents but is near several Indian reservations and centered in the so-called Golden Circle of natural parks in southern Utah and northern Arizona. Visitation at Lake Powell alone is now approaching two million visitor-days per year.

Three scenarios were developed. The first (A) represented existing conditions. The second (B) represented existing conditions plus a new visible power plant with no smoke plumes. The third (C) depicted a visible power plant with smoke plumes. No formal relationships were estimated between the characteristics of the plume, such as frequency and intensity, emission rates or control costs.

Application of the Bidding Method

Bidding methods were selected because of the limited resident population and the central characteristics of the impact area as a national park recreation area.

An iterative bidding technique, much the same as in Randall et al. (1974), was employed. Regular and retouched photographs of the alternative scenarios using the Navajo power plant were presented to Lake Powell recreators and local residents. (The bidding instrument and stylized pictures are contained in Appendix I.) Respondents were then asked what was the maximum entrance fee they would be willing to pay to prevent construction of another plant (WTP^B = ES measures): first, where only the plant would be visible from Lake Powell (scenario B), and second, where both the plant and pollution would be visible (scenario C). All respondents would be required to pay the same daily fee. The questionnaire also analyzed zero bids and gathered socioeconomic information. Pretested personal interviews were completed with 19 local residents of Paige, Arizona, 20 motel visitors, 22 developed-campsite users and 21 remote-area campers.

Analysis of Results

Table 6.2 presents the mean bids by sample group for both proposed changes--A to B and A to C. The bids of residents are statistically significantly smaller than for nonresidents. This is due in part to income effects and because many local residents directly or indirectly derive their livelihood as a result of the plant's operation and find the impacts less offensive. The nonresident groups are statistically indistinguishable due to small sample sizes. The authors suggest that the level of bids "seem quite reasonable when compared to the average family expenditure of visitors at GCNRA (Glen Canyon National Recreation Area), which approximates $24 per day for 1973. This figure does not include expenditures for travel costs nor the cost of recreational equipment." (Page 339, parentheses added.) The values are statistically significantly larger to prevent visible power plants and pollution rather than just preventing visible power plants.

Table 6.2: Lake Powell Power Plant Siting Values

Group	Benefits in Dollars Per Day Per Visitor Party	
	Mean Bid: A to C ($)	Mean Bid: A to B ($)
Residents	1.75	0.87
	(0.22)	(0.20)
Remote	3.38	2.11
	(0.50)	(0.54)
Developed	2.60	1.08
	(0.41)	(0.29)
Motels	3.11	1.94
	(0.33)	(0.48)
Population sample means	2.77	1.58
	(0.19)	(0.24)
Estimated aggregate yearly bid	727,600	414,000
	(50.270)	(62,400)

Standard errors in parentheses.

Source: Brookshire et al. (1976), page 338.

Several other results were also reported. First, about 21% of the bidders gave rejection or protest bids, many indicating that the payment vehicle was unsatisfactory. A theoretical model presented suggested that if strategic bias was present the bid would be bimodally rather than normally distributed.[3] The bid distributions were reported and appear more normally than bimodally distributed, and there were no extremely large bids encountered.

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[3] This is because all recreators were to pay the same entrance fee, which would be used to fund environmental improvements. For an individual to strategically affect the results so they more closely resembled his true value rather than the sample mean value, he would have to significantly overbid or underbid relative to his true value (depending upon whether his true value was larger or smaller than the sample mean). Substantial strategic bidding would therefore lead to either a bimodal or, at least, flattened distribution of bids relative to a normal distribution expected from sampling theory.

The authors next examined the income effect as it potentially affects the difference between theoretical CV and EV measures (the study actually obtained ES rather than EV measures). The authors found that the measured income effect upon the actual EV bids received theoretically predicts that CV values if obtained, would have been of almost exactly equal magnitudes as the EV measures. This is in keeping with the theoretical arguments made by Willig (1976) and reported in Section 2.2.4, above; however, the application of ES and CS measures need not yield equivalent empirical values (see NUREG 1979; Randall and Stoll 1980; and Rowe and Blank 1981).

Aggregate Benefits Measures

To calculate aggregate benefits, projected visitor populations for each survey group were estimated. Visitor-party-days were then estimated by adjusting for length of visit and family size. Next, by applying the mean entrance fee bid per visitor-party-day to the aggregate visitor-party-day estimate, total benefits were estimated. "The results indicate that recreationists in GCNRA in 1975 were willing to pay $727,000 to avoid situation C, which is the pollution situation; and in order to avoid the stacks depicted in situation B, they were willing to pay $414,000." (Page 338.) The present value of these benefits through time using a 35-year horizon and 5% discount rates is $21 million to prevent situation C and $12 million to prevent situation B. The effect of the income distribution among the sample groups upon the aggregate bid was also examined. By increasing the income of any group by 10% and decreasing the income of all others by 10%, no significant influence upon the aggregate bid was determined. The effect of an income increase or decrease for all groups was not determined.

The study notes that there were fifteen national recreation areas within a 100-mile radius of the proposed Kaiparowitz site, so that the aggregate benefits of control would be considerably larger than those estimated for the Lake Powell site alone.

Evaluation Comments

The results of this study again indicate that the economic benefits of preventing visibility degradation and other related environmental damages are very large, on the order of $10-20 million at one of many potentially impacted sites. The study also found a high correlation of the results with the earlier Four Corners study. (A comparison of results is discussed in The Farmington study and in Section 6.2.6.)

The study has several rather serious weaknesses for application to policy decision making. First, proposed air quality levels are not measured or tied to emission rates and therefore are difficult to relate to costs of emission control. Further, the scenarios are designed and pictorially represented to compare natural visibility conditions versus the impacts of a new plant and plume; however, as 1979 conditions indicate, a correct analysis would require that the smoke plume of any new plant would need to be evaluated as an additional impact to those of the existing Navajo power plant.

A second problem is that the pictorial representations of alternative conditions suffer from a lack of consistency across scenarios as to the scene and the angle from which it is viewed. For example, scenario A is depicted with two pictures of canyons at roughly eye level, while scenario C shows two views of the power plant emitting smoke as seen from the air. The effect of these variations on the benefit measures is unknown.

Direct estimates of the extra impact of visible plumes *given* that a new power plant is already visible (B to C) were not obtained and can be estimated only by the difference between the mean bids for A to C and for A to B. Because the *plant is visible in both scenarios*, this value (B to C) may be considerably different from values received where a plume is visible but the plant is not (the plant may be behind a hill or, for most impacted recreators, the plant may be at a considerable distance). Aggregate benefits, which are carefully calculated for the Lake Powell recreators, cannot be easily extrapolated to other nearby recreation areas, since one plant cannot be viewed from all 15 sites within the 100-mile radius of the Kaiparowitz site. Only benefit measures for visibility impacts without a visible plant would be valid for extrapolation, and these figures cannot be derived from these results.[4]

Finally, it must be noted that the visual analysis of strategic bias does not constitute a formal or defensible test, since there is no knowledge of what the underlying bid structure would look like without strategic bias. The existence of strategic bias might simply amplify the variance of the bids while retaining the normal bell-shaped distribution.

6.1.3 The Farmington Study

The Farmington study, as reported in Rowe, Brookshire and d'Arge (1980a,b) and Blank et al. (1977) was funded by the Electric Power Research Institute to examine in depth how useful non-market experiments are for establishing values associated with aesthetic experiences.[5] The study attempted to establish the economic value of visibility over long distances in the Four Corners region. Additional efforts were made to examine and test for biases in bidding methods. The Farmington study also included the first attempt to use the household production function approach for examining how behavior changes in response to visibility changes. The results of this latter experiment are reported in Blank et al. (1977).

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[4] This discussion is based upon the original research report and is not consistent with the review and analysis of this study presented in the South Coast Air Basin Study (Brookshire et al. 1979, page 40).

[5] The Electric Power Research Institute is in no way responsible for the validity of the analyses contained herein.

Problem Formulation and Scenario Development

By 1976 the Four Corners region's air shed was rapidly becoming one of the most significantly impacted in the county. As previously noted, the Four Corners power plant had already affected visibility conditions in the Four Corners area, including Farmington, New Mexico, which is the largest community in close proximity. In 1976 the plant had 2,175 MW of power. Since the Randall et al. study, the San Juan power plant had begun operations in the region with 660 MW of power and planned to add an additional 1,000 MW to its capacity. In addition, four coal gasification plants with a total of 1,750 million cubic feet of syngas capacity had been proposed for the area (WESCO I and II and Burnham I and II). Each of these actual and potential emission sources are shown on Figure 6-1. An example of the visibility degradation from the Four Corners plant is shown on Figure 1-5 of the EPA report to Congress (1979). It was estimated that daily regional emissions of 400-500 tons per day of SO_2 were reducing typical visibility from natural conditions of 160 km to 100 km and that if emissions increased to 1,200 tons per day of SO_2, visibility would be further reduced to 60 km (Kneese and Williams 1978).

This study was the first in which the bidding method approach was used to develop scenarios specifically linked to physical measures of visibility levels and emission rates. Three alternative scenarios were developed with decreasing levels of visibility and a fourth with a visible power plant. The first (A) depicted a visual range of about 120 km, or marginally better than the current "typical" conditions. The second (B) represented a visual range of about 80 km, and the third (C) represented a visual range of about 40 km. Scenario D represented a combination of C plus the visible siting of the power plant. The frequency of the alternative scenarios, both in the study period and in the expected future, was unknown, although some idea of the potential expected future emissions and resultant visual range was later taken from Kneese and Williams (1978).

Each alternative scenario was depicted with regular photography using two standardized views from Farmington: one of Shiprock to the west, which is a prominent landscape feature, and the second of the La Plata Mountains to the north. The final photographs were chosen from a set taken at two-hour intervals over a five-day period, and very nearly represent actual visual ranges of 120, 80 and 40 km (see Rowe et al. 1980a, pages 4-5). The photographs do exhibit variation in time of day, coloration and cloudcover, which may have influenced the values reported by respondents (see Appendix 1).

Application of Bidding Method

As in the Four Corners study, bidding methods were selected because local land ownership and use characteristics did not lend themselves to accurate property value analysis. Second, a major objective of the study was to analyze the validity of the bidding method approach applied by Randall et al. (1974) and Brookshire et al. (1976) in the same impact area.

Respondents were provided variations on the typical iterative bidding procedure for proposed degradations in air quality from the highest level (A) to the lower levels (B, C, D). After an introduction and presentation of the photographs, both willingness to pay questions to prevent the change (WTP^B = ES measures) and willingness to accept compensation questions (WTA^B = CS measures) were posed to respondents. This was the first attempt in a visibility study to test the influence of the difference between WTP and WTA compensation approaches upon the valuations received for visibility.

Other attributes of the questionnaire were varied across respondents to examine the influence of bidding method questionaire design. Starting bids of $1, $5, and $10 were randomly preassigned to respondents. Electricity bill increments and payroll deduction payment vehicles were also randomly preassigned to resident respondents. Nonresidents were presented with a typical user fee payment vehicle. Zero and infinite bids were evaluated, and socioeconomic characteristics, including environmental stance, were obtained. Other compensating approaches and an interview evaluation were incorporated but are not discussed here. A copy of the questionnaire is included in Appendix 1.

Tests for information and strategic bias were incorporated into the questionnaire design. First the WTP bidding procedure was structured so that the individual presumed he would have to pay the average bid, not his own. Therefore, if an individual's value was above the average and he desired to increase the magnitude of the aggregate bid, he would have an incentive to increase his stated bid so that the mean bid would more nearly represent his own "true" valuation, yet he would not actually be expected to pay the higher stated bid. Second, to test for information bias and provide information almost necessary to bid strategically, randomly preselected respondents were provided "supposed" mean bids of prior respondents, which was, in fact, much lower than the true mean bids. Those respondents who did not receive this information prior to bidding were presented the same information after bidding and asked if they desired to revise their bids. Finally, all respondents were asked after their WTP bids if they would bid more if the aggregate amount was not enough to fund the proposed environmental protection.

Pretested personal interviews were administered to over 100 Farmington residents in their homes and 30 recreationists at the nearby Navajo Reservoir.

Analysis of Results

The most noticeable result is that the WTA^B (CS) bids were 4 to 14 times larger than the WTP^B (ES) bids and had a greater variability. Also, over half of the respondents gave infinity bids or refused to bid on the WTA^B approach, rejecting the concept of selling their "right" to the higher air quality level. The authors provide a variety of reasons to explain the large divergence between the WTP and WTA bids. First, the WTP values were income limited, whereas the WTA values were not. Second, implied liability rules or property rights may influence the values differently. The WTPB approaches essentially represent a "victim pays" concept, while the WTAB approaches place the liability for maintianing visibility with the power companies and the property right to higher levels of visibilities with the residents. This WTAB approach presupposes that the power companies will attempt to buy off the consumer rather than cleanse the air. (See Section 4.2 for discussion on these influences in the bidding process.)

The next significant result was that the starting bid significantly influenced the bids. For each $1.00 increase in the starting bids, the mean values increased by about $.60. Also, the method of payment significantly influenced the size of the bid, with stated bids using payroll deductions larger than for electricity bill increments.

Information bias was present, but strategic bias was not found. Those respondents who received false information understating the mean bid of other respondents prior to bidding consistently bid less than those who did not receive the information. A test for strategic bias was designed which asserted that environmentalists who received the information would increase their bid while conservationists would decrease their bids. After adjusting for zero rejection bids and very obvious problem bids (bids greater than 10 standard deviations from the mean), the test failed to find strategic bias.

The study raised a question as to whether the bidding process elicits the maximum WTP and/or whether respondents simply attempt to cooperate with the enumerator. One-third of the respondents who were told their bid would be too low to support the proposed environmental protection revised their bid upward.

To examine the importance of the survey instrument design biases upon a respondent's bidding behavior, bid functions were estimated representing a weighted average between the "true" bid predicted by socioeconomic variables as derived from utility functions (see Section 2.5) and the information received via the survey instrument (starting bids, payment vehicle, and other information). The authors report that for the WTP bids, the estimated coefficients indicate that the reported bids are nearly equally made up of the respondents' "true" valuation and survey information influences. On the other hand, the survey influences were not statistically significant for the WTA bids. In these cases the difference between starting bids of $1 and $5, for example, was insignificant relative to final mean bids ranging from $25 to $100.

A major element of the Farmington study was to specifically test for comparability with the two previous studies. All three studies are similar in general design but different in their application. The Farmington questionnaire was considerably longer and contained many tests on the bidding method procedures. The scenarios vary considerably across the studies. The Four Corners scenarios depicted unmeasured visibility conditions plus unreclaimed soil banks and transmission lines. The Lake Powell study scenarios differ from the Farmington study due to their setting at a lake and the focus upon plumes. The time periods of study are also several years apart.

Table 6.3: Farmington Study Results (Per Month, Per Family or Unrelated Individual)

Bid	Sample Size	Mean Bid	SE of the Mean Bid
Residents			
ESAB[a]	93	4.75	0.386
ESAC	93	6.54	0.576
ESACR	73	7.58	0.766
ESBC	93	3.53	0.462
ESAD[b]	93	6.85	0.592
CSAB	45	24.47	7.54
CSAC	35	71.44	23.14
CSBC	36	46.63	14.14
CSAD	31	113.68	37.69
Nonresidents ES bids (per day)[c]			
ESAB	26	3.00	0.77
ESAC	26	4.06	1.05
ESBC	26	2.53	0.65
ESAD	26	4.56	1.11

ES-CS Bids

ESAB	ES bid for situation A (120 km)[a] to B (80 km)
ESAC	ES bid for situation A (120 km) to C (40 km)
ESACR	ESAC bid revised when ESAC was stated to be too low
ESBC	ES bid for situation B (80 km) to C (40 km)
ESAD	ES bid for situation A to C with visible power plants
CSAB	CS bid for situation A (120 km) to B (80 km)
CSAC	CS bid for situation A (120 km) to C (40 km)
CSBC	CS bid for situation B (80 km) to C (40 km)
CSAD	CS bid for situation A to C with visible power plants

Source: Rowe et al. (1980a)

[a] ESAB, for example, represents a bid to maintain visibility level A rather than have visibility level B. "A" represents visibility of 120 km, "B" visibility of 80 km, and "C" visibility of 40 km.

[b] Visibility picture D depicted a power plant and visibility reduction to level C.

[c] Nonresident bids were obtained at the Navajo Reservoir, near Farmington New Mexico.

Accounting for the many differences between the studies, the empirical results were very similar. Randall et al. (1974) reported yearly bids for residents of $85 (A to C) and $50 (B to C) per household. The Farmington results for the most comparable situations were $82.20 and $57.00. Considering the offsetting influences of the Four Corners results, including environmental degradation other than visibility and power plants, and that there was a significant inflation rate between the studies, the results are remarkably comparable. The results of the Lake Powell Study for recreationists are also in close agreement with the most comparable applications of the Farmington study, which is for starting bids of $1.00 comparing best to worst. These results are reported in Table 6.6.

Aggregate Benefits Measures

Aggregate benefit measures for residents were obtained by two approaches and had nearly equal results (Rowe et al. 1980b). The first multiplied the mean bids of nine income groups by the projected number of individuals in each group in San Juan County, New Mexico. The second applied linear approximated bid curves, again aggregating across the local population. Nonresident aggregates were determined for Navajo Reservoir recreationists only based upon Bureau of Reclamation estimates of visitation. The authors report:

> When it comes to reporting aggregate benefits, our confidence lies primarily with the ES measures. The CS measures (and standard errors) are an order of magnitude greater. In fact, if just one infinity bid is accepted, the CS bids are immeasurably greater. Using a 10 percent discount rate over a thirty-five year horizon, the aggregate resident and recreationist benefit measure is $14.2 million for situation A to B and $19.2 million for situation A to C. Statistical confidence intervals have a spread of approximately ± $1 million in each case. The present value of the plant siting benefits amounts to $1.1 million. Apparently, the exact plant siting is of considerably less importance than the pollution effects of a plant in the general vicinity. (Rowe et al. 1980b, page 103.)

Evaluation Comments

In this study an effort was made to develop a standardized photographic presentation of air quality conditions and to link the conditions depicted in the photographs with actual visibility conditions in terms of visual range. The rate of local emissions that would produce the depicted visibility conditions were also roughly determined. In this way, the study established links between control of emissions and benefit measures for local residents and nonresidents. The standard photographs did have some variation in terms of lighting, time of day and coloration, but the effect of these on the results is unknown. No efforts were made to further define the scenario in terms of timing, frequency, location and the like, which is now recognized as important to useful benefit analysis. Only activity values were estimated in this study.

The Farmington study has received considerable attention because it was the first such study to detect a great many problems and biases in the results. This occurred in part because the survey instrument was specifically designed to statistically test for the such biases if they occurred. It has been suggested that these problems resulted because the good to be valued was poorly specified (EPA 1979). This is probably not the primary reason. Although many residents felt the degraded visibility depicted in the photographs was due to wind-blown dust rather than to power plant emissions, they generally realized that emissions could cause such degradations. Also, relative to other such studies, the determination and presentation of visibility conditions was fairly well done.

The problem appears to have been that the contingent market was not credible or acceptable to respondents which decreased the incentives for accuracy, making respondents more susceptible to variations in the questionnaire. It was well known that local power was supplied by the city-owned power plant, not the two large plants operating in the region that supply power to Southern California; consequently, many residents felt it inappropriate to pay to prevent pollution that results from power production for Southern California. This is also reflected in the very high rate of rejection or infinity bids for the WTA^B questions. The difficult task of valuing visibility was made more difficult and more susceptible to inaccuracies by the problems in the contingent market definition.

The problem in the contingent market was further reflected in the WTA^B questions. About one-half of all respondents rejected these situations by refusing to cooperate or giving infinity bids; many suggesting that such a situation was unacceptable. The WTA^B bids, which were the first to be reported for such a study, were considerably larger than the WTP^B bids and the difference was larger than would have been expected from the Willig (1976) or Randall and Stoll (1980) analyses. This again suggests that great care must be taken to define contingent markets and to account for property rights. The study also analyzed bid functions explicitly derived from utility functions, which related bids to socioeconomic variables, a step which had not been performed in earlier studies.

A final problem area in this study was the survey procedure which used a stratified random sampling from a reverse telephone directory and door-to-door solicitation. A substantial number of potential respondents who were contacted refused to participate (tally sheets were not kept) yielding a potential self-selection bias as discussed in Section 4.2. The resultant sample size for recreationists and for residents responding to the WTA^B questions was insufficient for thorough statistical analysis.

6.1.4 The South Coast Air Basin Study

The South Coast Air Basin (SCAB) study as reported by Brookshire, d'Arge, Schulze and Thayer (1979, 1980, 1981) was funded by the EPA and operated out of the universities of Wyoming and New Mexico. The study was specifically designed to perform and compare bidding methods and property value approaches for measuring benefits from air pollution control in the same region. Therefore, much of the research methodology was designed to implement both approaches and eventually to compare the resulting valuations.

Problem Formulation and Scenario Development

Severe pollution episodes in Los Angeles extending into surrounding communities and deserts, otherwise known as the (SCAB), are well known nationwide as among the worst of urban pollution problems. Numerous studies have demonstrated the accumulation and movement of the smog in the area. The most serious effects are reduced visibility and health-related impacts. The pollutants of primary concern are nitrous oxides, carbon monoxide, ozone and hydrocarbons and are primarily related to mobile sources, space heating and unique climatologic and topographic charateristics of the region.

Visibility conditions in the region range from less than 2 miles visual range upward. A visual range of 30 miles or more would generally be considered good. If no further pollution programs are implemented, increased degradation in air quality can be expected as the population increases.

Three scenarios with subsequent supporting photography were developed for the bidding method study to analyze the impacts of both increased and decreased levels of air quality. The A scenario depicted "poor" air quality as a visual range of about 2 miles. This situation is typical in a substantial portion of the L.A. area. The B scenario represented "fair" air quality, typified by a visual range around 12 miles, the predominant condition in the area. The C scenario depicted "good" air quality as a visual range of about 28 miles. This level is found mostly in communities closest to the ocean. No attempt was made to relate visibility changes to changes in emission rates from any particular source.

The alternative scenarios were depicted using regular photography (see Appendix A) and maps depicting areas with the different levels of air quality. The good and fair conditons were depicted with two views from Griffith Park Observatory in Los Angeles. One view was toward downtown, about 5 miles away. The second was toward the west showing several buildings 4 miles away and two sets of hills in the background. The poor scenario was depicted by similar pictures but at another location because consistent lighting and color characteristics could not be obtained for this air quality level at Griffith Park.

Application of the Bidding Method

All data and requirements necessary to perform both the property value and bidding method approaches for determining benefits associated with changes in air quality were available. The bidding method study did have one important advantage in that perceptions and values of the interrelated visibility aesthetics and health affects of air pollution could be sorted out. The property value approach can only do this implicitly by attempting to link pollution measures to calculated visibility and health impacts, but these calculated effects may not reflect the perceptions of local residents, which limits their usefulness.

The bidding method questionnaire was the most complex and lengthy to date (see Appendix 1). The questionnaire took respondents through a nine-step process to determine the individual's value of proposed changes in air quality using both a WTPG iterative bidding procedure and a substitution of activities and expenditures procedure. The questionnaire attempted to break down the total benefits in terms of visibility aesthetics, and acute health and chronic health values. It also used two alternative payment vehicles--a monthly charge and an extra payment on utility bills--where everyone was to pay his stated bid. Alternative starting bids ($1, $10, $50) were randomly selected, as was the period of time required to clean the air (2 or 10 years).

Several other issues were examined. Approximately one-half of the respondents were mailed a pamphlet describing the health effects of air pollution before they were interviewed in order to examine the influence of information upon reported values. Standard questions evaluating zero bids and obtaining socioeconomic data were also included. A great deal of other information relating to the individual's allocation of time and money depending upon air quality levels, household and neighborhood characteristics, and other social and philosophical perceptions was gathered, but the results were reported for very few of these variables.

The application of the questionnaire was specifically designed to minimize hypothetical biases. Due to the large variation in air quality across the SCAB area, respondents were familiar with the alternative levels being examined. To increase the reality of the situation, respondents were asked to bid only on proposed improvements from the current state at their location to the higher levels. Respondents in locations with existing air quality rated good were asked to bid on their WTP^G for improvements in air quality to a good level for the entire region.

A total of 345 respondents were eventually interviewed in 12 different communities. Potential respondents were first contacted by telephone to determine their willingness to participate. Unfortunately, many respondents who initially expressed a willingness to participate later refused, and additional interviews were set up using telephone and house-to-house solicitations.

Analysis of Results

The monthly mean bids for the total health and aesthetic benefits related to air quality improvements are reported in Table 6.4. Communities with existing conditions of poor air quality bid between $11 and $22 to improve local conditions to fair, with an overall average bid of $14.54. Communities with fair air quality bid between $5.55 and $28.18 to improve local conditions to good with an overall average bid of $20.21. Communities with good air quality bid between $17.95 to $67.15 to improve the whole region's conditions to good, with an overall average bid of $34.09. On the average, for all proposed changes the aesthetic, acute health and chronic health components constituted about 34%, 40% and 26%, respectively, of the total mean bids. One interesting result of the bids that was not reported but can be determined from the results is that the mean monthly value for proposed improvements from poor to fair and from poor to good are almost exactly identical ($0.13 difference).

As reported in Brookshire et al. (1979) numerous survey design characteristics were found to statistically influence the reported bids. The payment vehicle was found to be a significant influence in about one-third of the bidding situations. The starting bid was significant in about one-sixth of the situations. Information biases caused by the order in which bids were requested and whether individuals first received a health information pamphlet were also found. All of these influences were significant enough not only to influence individual community values, but to influence the mean values for the whole sample. The authors state that for vehicle bias the principal problem area appears to be in the aesthetic bids (see Brookshire et al. 1979, page 89). The proposed period of time to clean the air also affected the reported bids.

Bid functions were estimated, from which it was possible to determine the income elasticities of stated WTP, which varied from zero to 0.67. Most other results relating to rejection rates, protest bids, etc., were not reported.

Aggregate Benefit Measures

Table 6.5 reports estimated aggregate annual benefits ranging from .58 billion to .65 billion dollars for a 30% region-wide improvement in air quality. The exact aggregation procedure is not reported. For comparison with other studies the present value of these aggregate benefits over a 35-year horizon with a 10% discount rate ranges from 5.6 billion to 6.3 billion dollars. These estimated benefits were not tied to specific emission control methods and were not related to costs to improve air quality.

Table 6.4: South Coast Air Basin Study Bidding Results[1]

Total $ Bid for Local Air Quality Improvement from Poor to Fair[2]

Community	Mean Bid (per month) (standard error, #OBS)
El Monte	$11.10 (13.13,20)
Montebello	$11.42 (15.15,19)
La Canada	$22.06 (33.24,17)
Total Sample	$14.54 (21.93,56)

Total bid for regional air quality improvement to good at all locations[3]

Community	Mean bid (per month) (Standard error, #OBS)
Pacific Palisades	$67.15 (27.45,20)
Palos Verdes	$17.95 (3.91,19)
Redondo Beach	$20.46 (5.33,26)
Total Sample	$34.09 (8.78,65)

Total $ Bid for Local Air Quality Improvement from Fair to Good[2]

Community	Mean Bid (per month) (standard error, #OBS)
Canoga Park	$16.08 (15.45,34)
Huntington Beach	$24.34 (25,46,38)
Irvine	$22.37 (19.13,27)
Culver City	$28.18 (34.17,30)
Encino	$16.51 (13.38,37)
Newport Beach	$ 5.55 (6.83,20)
Total Sample	$20.31 (23.0,186)

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[1] Unadjusted total bids, including aesthetic, acute and chronic health values.

[2] These results are from Brookshire et al. (1980). There are several unexplained differences and unreported values from the original work, Brookshires et al. (1979). The standard errors appear to be reported for the individual observation.

[3] These results are from Brookshire et al. (1979) and report the value for region wide air quality improvements to good conditions bid by residents of areas with existing conditons of good. Standard errors are for the mean bid.

Table 6.5: Bidding Method Estimates of Total Benefits for Air Quality Improvement in the South Coast Air Basin (Approximate 30% Improvement in Ambient Air Quality)

	Mean Bid	Survey Study Preliminary Regression Results
Average ($) bid per household per month	$29**	$26***
Annual benefits (selected areas and groups of the South Coast Air Basin in billions of $'s)	$.65	$.58

Source: Brookshire et al. 1979, page 134.

**Based on maximum total bid with an adjustment for years to achieve improvements in air quality.

***Based on maximum total bid equation with an adjustment for the amount of air pollution information available to the household.

Evaluation Comments

The results of this study indicate that improving air quality in the SCAB would be very beneficial because of the large population that would receive both health and visibility aesthetics benefits. This is the first application of the bidding method to urban pollution problems. Comparisons with the SCAB property value study described below suggest that the benefit measures obtained are defensible.

An effort was made to define visibility conditions in terms of visual range reduction and to increase the control and standardization of supporting photography, but only a limited effort was made to link visibility conditions to specific rates and sources of emissions. Consequently, no formal benefit-cost analysis can be performed. An effort was also made to design the survey instrument carefully to increase the credibility of the proposed scenarios. Nevertheless, there were still substantial questionnaire design biases, particularly related to bids for visual aesthetics, for which there was no explanation. Also, in the survey procedure, as in the Farmington study, rejection rates were not tallied or analyzed.

6.1.5 The Grand Canyon/Southwest Parks Study

This study, which is a joint effort by the U.S. EPA, U.S. NPS, the University of Wyoming and the University of New Mexico (EPA 1981) is the most recent and most concerted effort to link emission rates and sources to visibility conditions and to economic benefits of control. The study is also the first attempt to estimate existence values and to determine values for respondents who are not physically on-site in the impact area. In this case, the area of concern is the national parks of the Southwest, of which the Grand Canyon is the most prominent, with the respondents interviewed in four major metropolitan areas. Three basic questions were addressed: These were, What is the value of controlling haze in the Grand Canyon? What is the value of controlling haze in all Southwest national parks? and What is the value of controlling plumes in the Southwest Class I areas?

Problem Formulation and Scenario Development

The parklands of the Southwest are considered unique national treasures. For many people these parks are valuable whether or not they have visited or ever will visit them; or in other words, there is not only a value associated with their use but also with their existence. The enjoyment of many of these parks is particularly related to their impressive visual aesthetics; therefore, if the ambient air quality is degraded, so are the values of the parks.

The Grand Canyon is the largest and probably the best known of these parks, particularly because of its impressive scenic vistas. Unfortunately, like many of the parks, it has experienced periodic bouts of air pollution from man-made (anthropogenic) sources and thus has become the subject of many controversies concerning air pollution in national parks. In fact, many assert that the presentation by Gordon Anderson (Friends of the Earth) to U.S. Congressional members of a series of photographs depicting severe air pollution in the Grand Canyon was a major influencing factor in the eventual passage of the 1977 Clean Air Amendment.

Although the national parks of the Southwest are all protected from air pollution, they are located in an energy-rich region. In the Four Corners states (Colorado, New Mexico, Utah, and Arizona) there are coal-fired electric-generating plants with about 10,000 MW of power with another 13,000 MW of power proposed for the 1990's. If all of these plants are developed without controls as to emission rates or location, severe visibility degradation could occur. These plants are now subject to the national goal and visibility regulations to control emissions so as to minimize adverse visibility impacts that will affect any Class I areas. Two questions are relevant: What rate and location of emissions will result in adverse impacts? and What is the economic benefit of these controls?

To develop scenarios of impacts, the authors concentrated upon SO_2 emissions in the area from coal-fired power plants. Emissions of SO_2 are a major portion of the fine particles which are directly related to visibility reductions. To estimate the potential impacts of the proposed new plants on visibility, a survey was performed to determine the maximum controlled and uncontrolled SO_2 emission rates of each existing and proposed plant. Increases in SO_2 were then distributed uniformly across all sites, and the effect on air quality was determined by calculating the resultant impact measured by changes in a physical measure called "green contrast" which can be directly linked to visual range. This uniform distribution must be taken as a weak approximation of the actual distribution of impacts, since the location of the sources as well as graphic features, etc., will greatly affect the level of impacts across the area. Recognizing this, the authors state:

> All three scenarios of future SO_2 emissions in the test region should be recomputed with the use of a long range transport model, allowing for: 1) the transport of distant emissions into the region; 2) the chemistry of SO_2 conversion to sulfate fine particulate; 3) the removal by dry and wet deposition of pollutants affecting visibility; and 4) the inclusion of smelter and urban emissions.

Three conceptual scenarios were developed. The first suggested no future visibility deterioration would occur, since smelter SO_2 emission may decrease more than SO_2 emissions increase from proposed coal-fired power plants. A second scenario was developed based upon controlled emission rates for existing and proposed plants in which emissions would increase by about 400 tons per day, which again would not significantly impact visibility. A third scenario was based upon uncontrolled future emission rates of 3,230 to 3,900 tons per day of SO_2, which would significantly decrease air quality. The controlled and variations upon the uncontrolled emission scenarios were used as the two basic alternatives for comparisons in the actual bidding process.

Application of the Bidding Method

Bidding methods were selected because they are the only method designed thus far to capture existence values (which the authors of this study include in their definition of preservation values).

Regular photography was used to depict alternative air quality levels. Respondents were shown five views depicting regional haze. Each view was depicted with five air quality levels--A (worst) to E (best). Three of the views were from the Grand Canyon, and one each was from Zion and Mesa Verde. The photographs, selected from the EPA/NPS regional visibility monitoring network photo file, exhibited a high degree of consistency across air quality levels for each view. By using the

EPA/NPS network, it was possible to obtain precise measurements of actual air quality conditions at the time of the pictures, which allowed selection of pictures closely representing the proposed alternative conditions. Level C pictures were selected to represent "typical" conditons. Levels A, B, D and E were selected to represent humanly perceptible increments in air quality. The uncontrolled emissions scenario, and subsequent decreased air quality, was most closely represented in some cases by the A level picture and in some cases by the B level picture. This inconsistency in the assignment of the photographic representations of the uncontrolled scenario, coupled with the assumption of a uniform emission impact approach, creates a problem in determining which bids (C to A or C to B) would appropriately represent a program of uncontrolled emissions in the region or at any specific location. Air quality levels D and E were included to evaluate the benefits of even more stringent air quality control programs. Sample slides for one view used for this study may be found in the back of the guidebook.

Participants were also asked about their willingness to pay to prevent a plume from being seen in a Class I area. Two photographs taken at Hopi Firetower Observation Point in the Grand Canyon were used: one with a plume and one without, with all other conditions the same. The authors note the source was believed to be a controlled burn.

Two versions of the survey instrument were implemented: one to obtain user values and one to obtain preservation values (user and existence values). After a brief introduction concerning visibility and after showing the photographs of the Grand Canyon, the respondents were categorized as to whether they had visited the area in the past or expected to visit it in the future, or whether they did not expect ever to visit the area. About one-third of those who had visited or expected to visit the Southwest parks were given the user value questions and about two-thirds of the users plus those who never expected to visit the park were given the preservation value questions.[6]

Individuals in each group were asked a series of bidding questions relating to preserving air quality at the Grand Canyon, then were asked what additional payments they would make to preserve air quality at all other Southwest national parks as well, and finally were asked what payment they would make to avoid plume blight. The survey concluded with typical socioeconomic questions. Park users were asked the maximum increase in entrance fees they were willing to pay to ensure air quality levels E, D, C or B would be the conditions they could expect on the day they were at the Grand Canyon, or any Southwest park (regional analysis) rather than the lowest level A (WTP^G = CS).[7] For plume blight, users were asked their maximum entrance fee increment they were willing to pay to ensure plume blight would not occur on the days they were at the park (WTP^B = ES). Preservation value respondents were asked the maximum they would be willing to pay on their monthly utility bills to preserve visibility at the Grand Canyon, then for all Southwest parks at air quality level C rather than at level B (WTP^B = ES). A similar plume blight question was also asked. To avoid starting bid bias, respondents were asked to check the appropriate value on a list of values (point selection) for each proposed air quality change; however, there is no evidence that this procedure does not also bias results by the selection and clustering of value points provided. Finally, standard zero bid evaluation questions were incorporated into the questionnaire. No other tests for survey design influence were incorporated.

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[6] No analysis of respondent uncertainty was undertaken. These researchers assumed zero uncertainty on the part of the respondent as to future usage rates so as to eliminate option values. This may lead to some problems, since respondents who state no expectation of future visitation but who are uncertain may not be bidding on a zero rate of future visitation. On the other hand, option value is assumed to be zero for actual users and those who state they will use the park but may, in fact, be uncertain of future use. Option value is therefore likely to be included in the preservation value bids by users. and non-users.

[7] It seems that an appropriate benchmark would have been established by first asking the maximum entrance fee respondents would have been willing to pay given scenario A.

Pretested questionnaires were applied to a stratified random sample of residents of four metropolitan areas in the summer of 1980. Four hundred fifty preservation questionnaires were completed: 115 in Albuquerque, 127 in Los Angeles, 110 in Denver and 98 in Chicago. One hundred sixty-six user value questionnaires were completed; 61 in Albuquerque, 60 in Los Angeles and 45 in Denver. The questionnaires were administered through a random door-to-door solicitation (see footnote 11, page 4-27 of this guidebook).

Analysis of Results

Mean bids of all respondents in the four cities are reported in Table 6-6. A noticeable feature of the user value bids is the apparent increasing returns to scale from improvements in air quality. The authors attribute this to a Dubos effect which asserts that as the environment deteriorates, people care less and less about future deterioration, or, in other words, people put a special value on pristine environmental conditions.

The preservation value questionnaire was undertaken to obtain both user and existence values. Thus, by comparing the reported preservation values with user values the importance of existence values could be derived. Unfortunately, the bids are obtained for non-comparable scenarios: A to B, A to C, etc. in the user questionnaire, a WTP^G approach; and for C to B in the preservation questionnaire, a WTP^B approach. It is not necessarily the case that the A to C bid minus the A to B bid should equal a B to C bid due to non-linearities in value functions, or that a B to C bid would equal a C to B bid due to the effects of changes in implicit liability rules. Nevertheless, making these assumptions and the assumption that the user values and preservation values received are both accurate measures of benefits, the preservation values (especially the existence values) are found to overwhelm user values. For example, from the reported bids to protect only the Grand Canyon, we calculate the following: The average user attended the park .283 days per year and would be willing to pay an extra $1.08 per recreation day to have conditions C versus conditions B (calculated as the A to C bid minus the A to B bid).

TABLE 6-6

GRAND CANYON/SOUTHWEST PARKS STUDY RESULTS

Bid Type	Mean Bid	S.E.'s of the Mean*
USER QUESTIONNAIRE (user values using a per day park entrance fee based upon 166 maximum number of observations)		
Grand Canyon Protection		
WTP^G for A to B	1.68	.126
A to C	2.76	.137
A to D	3.90	.200
A to E	5.15	.663
Additional for Regional Protection		
WTP^B for C to B	4.29	.717
Additional for Plume Avoidance		
WTP^B	4.10	.425
PRESERVATION QUESTIONNAIRE (user value plus existence value using a monthly utility bill increment based upon 450 maximum number of observations)		
Grand Canyon Protection		
WTP^B for C to B	5.38	.785
Additional for Regional Protection		
WTP^B for C to B	4.58	.701
Additional for Plume Avoidance		
WTP^B	3.53	.467

Source: EPA (1981)

*Calculated assuming reported S.E.'s are for the distribution of values, not the mean value, and assuming all of the observations are complete.

This amounts to an average $.305 user value per year. On the other hand, the mean preservation bids for C to B were an extra $5.38 per month on an individuals utility bill or $64.56 a year. The authors assert that preservation bids of users and non-users are not significantly different. Therefore, the implied existence value is 210 times as large as the calculated user values. Using the same approach, existence values are 11 times as large to preserve the remainder of the region, and 21 times as large to prevent plume blight in the Grand Canyon. The fact that this ratio is so much larger for the Grand Canyon as compared to the Southwest parks suggests the importance of its role as a unique national treasure.

The authors examine zero bids and find between 0 and 20% rejection bids depending upon the scenario; although, how these bids are handled is not reported. Other rejection bids are not reported. No tests for other instrument biases were conducted. A linear bid fucntion analysis of preservation bids finds that only age consistently influences the bids. The estimated income elasticity, when significantly different from zero, is very small; ranging up to only .05. In fact, the estimated bid functions explain very little of the deviations in the reported bids across respondents (R^2 = .05).

Aggregrate Benefit Measures

Bids from the preservation value questionnaires are aggregrated to total benefits for residents of six Southwestern states (California, Colorado, Arizona, Utah, Nevada, and New Mexico) and for the entire continental United States as reported in Table 6-7.

Table 6.7: Aggregate Benefit Measures From the Grand Canyon/Southwest Parks Study

BENEFITS FOR PRESERVING VISIBILITY IN:	DOLLARS (in Millions) Annual (Present Value @ 10%, 30 yrs) Southwest	U.S.
The Grand Canyon	$470 ($ 4,430)	$3,370 ($ 31,770)
The Region (Grand Canyon, Mesa Verde and Zion)	$889 ($ 8,380)	$5,760 ($ 54,300)
Avoidance of Plume Blight in Grand Ganyon	$373 ($ 3,516)	$2,040 ($ 19,230)

Source: U.S. EPA (1981)

Benefits are related to emissions by estimating that complete decontrol of projected regional power plant emission of SO_2 in 1990 would decrease visibility by the same amount or more than is depicted in the preservation value questionnaire scenario. Thus, one can interpret the regional potection figure of almost 9 billion dollars per year as the benefits of power plant SO_2 controls projected to be in place in the region by 1990.

Evaluation Comments

This study attempted to use the state-of-the-art in contingent market methods to address two issues beyond the valuation of a unique environmental resource, both of which have heretofore received limited attention. These were the relative magnitude of user values and existence values and the cumulative impact of regional energy growth upon regional air quality. The study has also undertaken the most detailed effort to link emissions to air quality, to photographs, and finally to economic valuations. By doing so, the study provides results of great interest. Specifically, preservation values of the Grand Canyon and other Southwest parks are very large and may well exceed all emission control costs in the region.

Limitations in the state-of-the-art suggest that the study may, however, have tried to do too much. For example, on the technical non-economic side, the researchers were forced to use an assumption of uniform distribution of impacts across the region due to limitations in dispersion modeling. Second, due to limited historical photograph files, the researchers were unable to obtain photographs depicting the same rates of change in air quality for each scenario at each site. In other words, the change in air quality depicted between any two air quality levels, say C to B, is not consistent across sites. These problems weaken the comparison of the benefit estimates to cost estimates at each site or across the region, but the discrepancies are not so serious as to eliminate ballpark comparisons for broad policy considerations.

The bidding method questionnaire was desigend to minimize many potential problems and, to its credit, received a very high response rate. Further, it demonstrated that existence values are important and may overwhelm user values in importance. This is not unexpected. Even if each individual's existence value is small, the ratio of users to non-users suggests that aggregate existence values may exceed the aggregate user values. What is unexpected is that even for users the implied existence values are 11 to 200 times as large as their user value. In other words, the results suggests that user values are insignificant to the valuation of the Grand Canyon and other Southwest parks, even to users. One problem which may be contributing to this result is the lack of attention given to the respondents' uncertainty about future use (see Footnote 6 above). Consequently the preservation bid includes user, existence and option values related to prospective future user benefits. This issue of uncertainty related to future use will need greater attention in any study addressing future use values or existence values.

There are several other areas of concern with the bidding method results and their interpretation. First, there is a lack of consistency in approaches between the user and preservation (user plus existence values) questions. They are different types of questions (WTP^G, WTP^B) over different sets of impacts (A to B, A to C, etc. vs. C to B). Next, are the findings, based only upon a comparison of mean bids, neither the rate of park use, nor distance from the site affects preservation values. A more in-depth analysis of bids as a function of distance, socioeonomic characteristics, use rates, etc., all at once may have found otherwise. The authors' assertion of a Dubos effect may be the case, but is subject to question. The rate of increase in the user value bids is not significantly different from zero. A closer examination of the photographic characteristics (Table 3, p. 23) shows that the air quality conditions (measured by green contrast) on average also increase at a small but increasing rate, further diminishing support for the Dubos effect.

The aspect of the bidding method results which seems to have the most limited credibility is the assumption that all households across the country would pay monthly increments in local utility to fund environmental improvements in the Southwest. The empirical finding that most households would be willing to pay such a substantial amount (about $160 per year) to protect the Grand Canyon and the Southwest from haze and the Grand Canyon from plume blight combined with the approach may lead to questions about the accuracy of the results. Finally, extrapolating to United States totals from results of Albuquerque, Los Angeles, Denver, and Chicago, while ignoring the heavily populated mid-east, eastern seaboard, and the South, is particularly dangerous.

6.1.6 A Comparison of Visibility Related Bidding Method Studies

Table 6.8 compares 19 elements of the five bidding method studies previously described. The studies were conducted sequentially. Four of the studies were concerned with the benefits of pollution control in the Southwest where many Class I areas have been impacted by power plant development, and one study was concerned with benefits of urban pollution control (SCAB). The number of interviews completed in each study was sufficient for defensible statistical analysis; however, the sample size for subgroups in the Lake Powell study and for recreationists in the Farmington study were too small to do much analysis beyond reporting mean bids. The percentage of interviews that was usable was very high in each study, ranging from about 70% up. What is critical but infrequently reported in the studies is the exact sampling procedures employed and the number of individuals contacted who refused to participate. If the nonparticipation ratio is high, as was the case in many studies, there may have been self-selection problems that biased the randomness of the survey. Future studies will need to plan and document survey efforts more carefully to insure that the benefit analysis is defensible.

The scenario development (element 6) has evolved from general scenarios presented in Randall et al. (1974), which typified air quality variations from "worst" to "best" and lump several impacts together, to specifically defined scenarios designed to separate out visibility aesthetics, power-plant siting, and health-related impacts.

The length of bidding method questionnaires, measured by the number of questions (element 9) has been continually increasing. This represents a trend to include time and expenditure substitution data to

TABLE 6.8

A SUMMARY COMPARISON OF BIDDING METHOD VISIBILITY STUDIES

Design Elements	Four Corners Study	Lake Powell Study	Farmington Study	South Coast Air Basin Study	Grand Canyon/ Southwest Parks Study
1. Time	1972	1975	1977	1978	1980
2. Place	Four Corners	Lake Powell	Farmington, NM	South Coast Air Basin	Four Urban areas evaluating the Grand Canyon and South-western parks
3. Respondents	Residents/Recreationists/ Indians	Residents/Recreationists	Residents/Recreationists	Residents	Recreationists and Non-Recreationists
4. Total Interviews Conducted (percent usable)	1,099 (69%)	104 (79%)	130 (92%)	345 (NR)	NR
5. Usuable Interviews by Respondent Group	526/150/71	19/63	93/26	345 (NR)	166 / 450
6. Scenarios	Emissions, Strip Mining, Transmission Lines A-Worst B-Middle C-Best	Air Quality and Power Plant A-No Plant B-Plant, No Plume C-Plant with Plume	Air Quality and Power Plant A-Visibility 120 km B-Visibility 80 km C-Visibility 40 km D-C + visible plant	Air Quality and Health A-Poor visibility 2 miles B-Fair visibility 12 miles C Good visibility 28 miles	Air Quality A-worst to E-Best with C = typical for Haze, A-none, B-plume, for plume analysis
7. Length (# Questions)	NR	9	33 to 49	79 to 450	NR
8. Value Types	Activity	Activity	Activity	User	User, Presentation
9. Question Type	WTP^G, WTA^B	WTP^B	WTP^B WTA^B	WTP^G, WTA^B	WTP^B
10. Bid Scale	Iterative Bidding	Iterative Bidding	Iterative Bidding	Iterative Bidding	Point Selection
11. Payment Vehicle	User Fees/Electricity Bill/Sales Tax	User Fees	Utility Bill/Payroll Deduction/User Fee	Utility Bill/Monthly Payment to Conservation Fund	Electricity Bills/ User Fees
12. Mean Recreation Income	NR	$22,000	$11,900	-	$25,300 to $30,800
13. Mean Resident Income	NR	$16,000	$15,200	$8,800 to $36,242	$19,000 to $30,570
14. Income Elasticities of Bids: a-Residents b-Non-Residents	0.39 to .65 .09 to .16	NR	0.25 to 0.36 (ES Bids) 0.0	.00 to .67	.00 to .05
15. WTB Bid Comparisons					
a. Best to worst-average yearly bid for resident households (# of respondents, standard error)	$85.00 (526,4.31)	-	$82.2 (93,9.10)	$245.20 (48,55.3)	See Text

TABLE 6.8 (Continued)

Design Elements	Four Corners Study	Lake Powell Study	Farmington Study	South Coast Air Basin Study	Grand Canyon/ Southwest Parks Study
15b. Best to Moderate-Average yearly bid for residents households (#of respondents, standard error)	$50.00 (526,3.02)	-	$57.00 (93, 4.63)	$243.12 (186, 20.34)	C-B $119.52 (450, 17.88)
c. Middle to worst-Average yearly bid for residents households (#of respondents, standard error)	-	-	$43.00 (93, 5.54)	$174.48 (56, 35.18)	See text.
d. Best to worst-Average daily bill ($1976) Recreationists with $1.00 starting bid (#of respondents, standard error)	-	$ 2.95 (19, 0.2)	$2.44 (26, 0.23)		See text.
16. Tested for Biases/Found Biases	No/No	No/No	Yes/Yes	Yes/Yes	No/No
17. Aggregate Yearly Value	A-B = $15.54 million A-C = $24.57 million	A-B = $414,000 A-C = $727,000	A-B $1.47 Million (ES) A-C $1.99 Million (ES) A-D $2.14 Million (ES) B-C $1.1 Million (ES)	30% Improvement $ .58 to .65 Billion	C-B = $5.76 billion
18. Present Value (years/ discount rate)	NR	A-B = $12 million A-C = $21 million (35, 5%)	A-B $14.2 Million (ES only A-C $19.2 Million 35,10%) B-C $11.1 Million A-D $20.6 Million	$5.6 to 6.3 Billion	C-B = $54.3 billion
19. Total Value Comments	Values for total affected Four Corners Region	Examined 1 of 15 potentially impacted parks	Value for San Juan County New Mexico and Navajo recreation area only. Total affected area up to ten times larger	About one-third of benefits are related to aesthetics, two-thirds to health	Above reports user plus existence benefits for nation as a whole to protect Grand Canyon and southwest parks from haze.

complement the reported bid; however, if response fatigue and inaccuracies (as well as costs) are to be minimized, this trend should be reversed by careful modeling, selection and definition of alternative scenarios and survey instrument design.

Elements 8 and 9 refer to the type of values examined--activity, option and existence, and the type of WTP or WTA measures used. WTP^B (an ES measure) and WTP^G (a CS measure) measures have become the most frequently used. The two applications of the WTA^B measure both incurred over 50 percent rejection or protest bids, indicating they did not present a realistic, credible or acceptable situation to respondents. Activity values only were obtained in all studies except the Grand Canyon/Southwest Parks study.

Most applications used the classic iterative bidding approach (element 10); however, the more recent efforts have been directed toward investigating alternative approaches. Payment vehicles (element 11) were most always user fees for recreationists and electricity bills for local residents. Both of these have an element of reality, since they directly relate to the recreation experience or to the consumer who would eventually pay for emission control.

Tied to the payment vehicle is the question of whether an individual has the ability to gauge the impact of the payment vehicle procedure or of his bid upon annual, or lifetime, expenditures. Does the individual recognize the total impact of a small change in sales tax, or increases in monthly utility bills and does the recognition of these impacts influence bidding? Only one air quality bidding method study (SCAB) has provided selected respondents with "life tables" of what a monthly bid amounts to over a number of years. Unfortunately, no results were reported of how presentation of these tables influenced mean bids.

In all of these studies income has been found to be statistically correlated with reported bids. Mean income for recreationists, residents and the calculated income elasticity are reported in elements 12-14. In each case reported, the income elasticity was less than one for residents and very nearly equal to zero for recreationists; therefore, large income changes would have been necessary to significantly change mean bids and the aggregate benefit measures.[8]

Element 15 reports the mean bids for up to four situations in each study. Because each of the proposed changes in air quality and the related impacts varied greatly across the studies and were in different periods of time, the figures cannot be precisely or statistically compared; therefore, best, worst and moderate rates of impacts are used for the sake of comparison. Recalling that the SCAB results were one-third visual aesthetics and two-thirds health related, while health effects were minimal in the other studies, the results are remarkably similar for each of the most comparable situations. Annual resident household values for the visibility component for best to worst is in the $80 range for each study; $60 to $80 for best to moderate; and $40 to $60 for moderate to worst. The average daily entrance fee increment bid by recreators is also consistent across studies. If other factors, such as inflation and impacts components, were to be adjusted, the values would be even more comparable across studies. This suggests that with a sufficient number of studies for a variety of locations and impacts, and with more work on how changes in the characteristics of the scenario affect valuations, bidding method results will be at least weakly transferable across sites at some future date. It should be noted that the results of the Grand Canyon study can only be carefully compared to the others because it also estimates existance values.

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[8] The income elasticity for the Lake Powell study (Brookshire et al. 1976) was not reported but can be calculated indirectly from equation 5.11, page 342. This was not done here, because the equation combines values for both residents and recreators; this overstates the income elasticity, because residents had lower incomes but also felt less of an impact, because many derived their income directly or indirectly from the plant and many are acculturated to its impacts.

Element 16 shows if the studies formally tested for and found design biases affecting the results. Both the Farmington study and the South Coast Air Basin study tested for and found biases. The problem in the Farmington study can be identified as a hypothetical bias problem which manifested itself through increased measurement errors and biases. No explanations are provided as to why the biases were found in the SCAB study, particularly when the alternative scenarios are so well known to local residents.[9] Several bidding games for other goods have tested for biases and and have not found them (Brookshire et al. 1978; Randall et al. 1979; and Thayer, 1981). While all applications of the bidding methods may not yield these biases, all applications to visibility benefit analysis that had formally designed and statistically implemented bias tests found biases. In some cases the biases were not large, but the results indicate that respondents do have trouble putting value upon visibility and that they are influenced by the survey and questionnaire design (see Rowe et al. 1980a).

Elements 17-19 report total yearly and present value figures and summary comments. The total value figures vary greatly across studies because the size of the impacted population also varies substantially and because several studies examined the impacts only upon selected subsets of the totally impacted area (all but the Grand Canyon and SCAB studies). Future studies will need to more carefully define and calculate aggregate benefits to increase the defensibility of the analysis.

6.2 Hedonic Approach Case Studies

The five property value studies in this section are the Washington D.C. study, by Nelson (1978); the Boston study, by Harrison and Rubinfeld (1978); the Denver Study, by Bresnock (1980); The South Coast Air Basin study, by Brookshire et al. (1979; 1980); and the San Francisco Bay Area study, by Loehman et al. (1980). They are all based, at least in part, on the Rosen-Freeman theoretical framework for applying the hedonic price technique to residential property values to estimate the WTP for air quality at the residential site. This approach relies on the initial work with hedonic prices by Griliches (1971) and the fairly extensive housing market studies represented by studies such as Kain and Quigley (1972).

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[9] Brookshire et al. (1980) reports that biases were not found in the SCAB study (page 14) even though the original research reports clearly show starting bid, information and payment vehicle biases were found (Brookshire et al. 1979, pages 80-103) for subsets of the bids from which it can be inferred that these biases for the total bids were also present.

It would be useful for public policy purposes to know what the benefits of reducing urban air pollution would be. Of particular concern is that national ambient air quality standards are being violated for some pollutants in many urban areas around the country. The national primary standards, listed in Table 6.9, are based on the health effects of the various pollutants. National secondary ambient air quality standards address protection of the public from all adverse effects of air pollutants including aesthetic impacts. As shown in Table 6.9, secondary standards differ for only sulfur dioxide and particulates.

Although health impacts of urban air pollution have been the primary regulatory concern, there is evidence that urban residents are concerned with both effects[10] and researchers have recognized that property value studies can measure them both. However, none of these studies have attempted to separate aesthetic and health impacts. It may be possible to link specific pollutant concentrations to visibility impacts, such as visual range or discoloration, but in the urban areas that have been studied the different available pollution measures have tended to be highly correlated with one another. The property value approach cannot be used to distinguish whether residents are concerned with health effects or aesthetic effects or both, if these effects are highly correlated, and especially if both effects are caused by the same pollutant. Hence, the pollutant chosen for a study using the hedonic price technique is generally considered a proxy for all air pollution impacts in that study area.

In each of these studies a hedonic price function for residential property values has been estimated. Because the list of variables used in this function is lengthy and varied for each study, the variables used in each study are listed in Table 6.10 in Section 6.2.6. Some of the studies have reported the mean marginal implicit price of air pollution from this function. This tells how much a unit reduction in air pollution would add to the market value of the property. When the hedonic price function is nonlinear this price is not constant; therefore, it is usually evaluated at its mean value for comparison purposes. In each of the studies, the marginal implicit price of air pollution for each household is used as the dependent variable in the WTP function from which benefit estimates of a reduction in air pollution (or damages of an increase) can be derived. Some of the studies have derived such benefit estimates for an expected or potential change in air pollution.

This review emphasizes the data used, the relationship estimated, the results obtained, and when applicable, the scenario used to develop benefit estimates in each of the studies. The hedonic price technique requires application of the appropriate statistical techniques, particularly regression analysis, the details of which are complex and beyond the focus of this review.

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[10] For instance, the SCAB study (Brookshire et al. 1979 and 1980) found that approximately one-third of the Los Angeles area residents' stated WTP for an improvement in air quality was attributed to aesthetic effects.

Table 6.9: National Ambient Air Quality Standards

Pollutant		Concentration Limit[f] micrograms per cubic meter ($\mu g/m^3$)[c]	parts per million (ppm)[d]	Averaging Time
carbon monoxide		10,000	9	8 hours[a]
		40,000	35	1 hour[a]
ozone[e]		160	0.12	1 hour[a]
hydrocarbons		160	0.24	3 hours[a]
nitrogen dioxide		100	0.05	1 year
sulfur dioxide	primary	80	0.03	1 year
		365	0.14	24 hours[a]
	secondary	1,300	0.05	3 hours[a]
particulate matter	primary	75		1 year[b]
		260		24 hours[a]
	secondary	150		24 hours[a]

Source: 40 CFR, Part 50 (1980)

[a] not to be exceeded more than once annually

[b] geometic mean

[c] 1 $\mu g/m^3$ = .1 mg/hm^3

[d] 1 ppm = 10 pptm = 100 pphm

[e] The ozone standard was lowered from .08 to .12 in 1978.

[f] Primary and secondary standards are the same unless otherwise noted.

6.2.1 The Washington D.C. Study

Study Area Description and Data Selection

For the first application of the estimation procedure suggested by Rosen (1974) and Freeman (1974) to obtain demand and supply equations for urban air quality, Nelson (1978) studied the Washington D.C. Standard Metropolitan Statistical Area (SMSA).

U.S. Census data from 1970 for property values and for several house and neighborhood characteristics were used. For neighborhood accessibility and amenities the author used travel time to 75% of metropolitan employment, travel time to the CBD, crimes per million dollars of property, property tax rates, public school expenditures per student, and whether the census tract was adjacent to a scenic river. Air pollution measures used were average monthly geometric mean in micrograms per cubic meter ($\mu g/m^3$) of total suspended particulates (TSP) and average daily arithmetic mean in parts per million (ppm) of oxidant during summer.

Census tracts with at least 200 single-family owner-occupied units were selected. These included 231 urban and 235 suburban tracts. Eleven tracts that did not fit the general pattern of property values and characteristics were eliminated. These had unique features that caused property values to be unusually high: five were in Georgetown and three were near Capitol Hill.

Hedonic Price Function Estimation

Separate hedonic price functions were estimated for TSP and oxidant. Both TSP and oxidant were found to have significant negative influence on property values, though the TSP coefficient was somewhat stronger. All the variables except school quality and crime rates were found to be statistically significant in influencing property values. Travel time to employment was found to be a preferable measure of accessibility than travel time to the CBD.

Linear, semi-log, inverse semi-log and log-linear functional forms for the hedonic price function were tested. Though results did not vary greatly, the log-linear form was chosen as the best fit. Because the second derivative of the log-linear form with respect to air pollution will always be positive, this functional form constrains the marginal implicit price for air pollution to be an increasing function of air pollution. This means that the marginal implicit price becomes a smaller negative value as air pollution increases. (See Section 4.3.2.)

The final hedonic price function explained 88% of the variation in property values. When divided into urban and suburban tracts, significantly different hedonic price functions were not found, and hence there was no evidence of market segmentation along these lines. The results indicated that the mean marginal implicit price of TSP was \$69 per $\mu g/m^3$ and of oxidant was \$15 per .001 ppm, which means that a one $\mu g/m^3$ reduction in TSP was associated with an average property value increase of \$69 and a .001 ppm reduction in oxidant was associated with an average increase of \$15 in property values.

WTP Function Estimation

This study is unique in that both willingness to pay for air quality and supply of air quality functions were estimated. The author hypothesized that WTP is a function of air quality, median family income, and median persons per unit, and that supply is a function of air quality, population density, and travel time to 75% of metropolitan employment. The air pollution measure was transformed to an air quality measure by taking the reciprocal of the TSP variable. This had the effect of making WTP and supply functions of a good (air quality) rather than a bad (air pollution). The expected inverse relationship between the marginal implicit price and the level of air quality was obtained, indicating that willingness to pay for air quality decreases as air quality increases. The results indicate that the supply is somewhat inelastic (unresponsive) to the marginal implicit price of air quality. The other four studies discussed here have assumed that it is perfectly inelastic.

Benefit Estimates

Benefit figures for a change in air pollution in the Washington D.C. area were not estimated. However, from his WTP function it would be possible to derive benefit estimates for a reduction in TSP, and possibly other pollutants, expected to be achieved by a specific program, which then could be compared with the costs of the program. Whether the TSP variable was correlated with other pollution measures would have to be considered to determine whether the estimated function represented willingness to pay for a reduction in some or all of the air pollutants then found in Washington D.C. or for a reduction in TSP only.

Evaluation Comments

The choice of the log-linear functional form for the hedonic price function was justified by the assertion that the slope of the marginal implicit price function is not constrained by this form because it depends on the ratio of property value (PV) to air pollution (AP). When $PV = aAP^b$ it is true that the marginal implicit price function is given by $b \cdot (PV/AP)$. However, because there is an inverse relationship between PV and AP, as AP increases PV/AP will always decrease. Also, because of the inverse relationship between PV and AP, the parameter, b, will be negative. A negative constant times a decreasing number results in an increasingly small negative number, hence the marginal implicit price function will always increase as air pollution increases. The same conclusion is obtained by taking the derivative of the marginal implicit price function with respect to air pollution, which is the second derivative of the hedonic price function. For all $PV \geq 0$, $AP \geq 0$, and $b < 0$ as is expected, the second derivative will always be positive. This conclusion would not hold for $b > 0$. Hence, the choice of the log-linear form has restricted the slope of the marginal implicit price function for air pollution to being positive.

To estimate willingness to pay for air quality, the air pollution variable was transformed into a measure of air quality by taking the reciprocal of the particulate measure, which imposes a relationship between air quality and air pollution that may not be correct. We can expect an inverse relationship between air quality and air pollution, but the exact form of this relationship is unknown. If such a transformation was appropriate, it should have been used for estimating the hedonic price function as well.

The specification of the supply function for air quality at the residence used in this study has been the subject of controversy. Freeman (1979a) suggests that it would be more appropriate to concentrate on changes in housing density rather than on the tradeoff between residential and other land uses that Nelson emphasizes in his discussion. Some housing market studies have estimated supply functions for housing attributes. Witte, Sumka, and Erekson (1979) estimate the supply of three housing attributes--dwelling quality, dwelling size, and lot size--as functions of the quantity of the attributes and supplier characteristics that are expected to influence the supplier's efficiency and experience. More work needs to be done to verify the factors that appear to influence supply of housing attributes and to identify factors that may not have as yet been considered.

6.2.2 The Boston Study

Study Area Decription and Data Selection

Harrison and Rubinfeld (1978) studied the Boston SMSA. The air pollution measures used were annual average parts per hundred million (pphm) nitrogen oxides (NO_x) and annual average milligrams per hundred cubic meter (mg/hm^3) TSP. More than half of both pollutants were produced by stationary sources which tended to be in the central city. The means of these measures were 5.55 and 6.31, respectively. These were close to the national primary ambient air quality standards, indicating that violations were occurring in some part of the study area. NO_x approximately ranged from 3 to 9 pphm across the area. NO_x and TSP were highly correlated with one another. These measures were generated by an air pollution dispersion model for zones that were larger than census tracts but that covered the entire metropolitan area, so that pollution estimates were available for tracts that were not located near monitoring stations.

They selected 1970 U.S. Census data for property values and for several house and neighborhood characteristics. To represent neighborhood accessibility and amenities, they used access to radial highways, distance to employment, crime rates, property taxes, student/teacher ratios, whether the tract was adjacent to the Charles River, percentage of non-retail business acreage, and percentage of land zoned for large lots.

Census tracts with no housing or that were dominated by an institution were eliminated from the sample, leaving 506 tracts. Each town in the area was made up of several tracts, and some data, such as property tax rates and land use, were for the entire town rather than for the individual tract.

Hedonic Price Function Estimation

Two pollution measures were used in separate hedonic price functions due to their high correlation with one another. Both pollutants were found to have a significant negative influence on property values. The coefficients of the non-pollution variables were virtually the same in the two equations, which the authors cited as evidence that households are averse to pollution in general rather than to any particular pollutant. Both of these equations explained a little more than 80% of the variation in property values.

The semi-log functional form was chosen as slightly superior to the linear form. Possible nonlinearities in the pollution variables were explored, and NO_x^2 and TSP^4 were chosen as the specifications of the pollution variables with the best fit. This estimated functional form implied that at the mean value of NO_x and the other variables, the marginal implicit price of air pollution became an increasingly large negative value as NO_x increased; however, the estimated TSP equation implied that at the mean value of TSP and the other variables the marginal implicit price of air pollution became an increasingly small negative value as TSP increased. As discussed in Section 4.3.2, either a positive or a negative slope may occur, but obtaining contradictory results in the same study area for pollutants that are highly correlated is difficult to explain.

Unlike the results of the Washington D.C. study, the age of the house was found to be insignificant, and the crime and school variables were found to be significant. The land use variables were not significant. Harrison and Rubinfeld reported that at the mean value of NO_x and the other variables, the marginal implicit price was $1,613 for a one pphm reduction in NO_x.

WTP Function Estimation

Willingness to pay for a reduction in NO_x was estimated as a function of NO_x and median family income. The authors assumed that the supply of residential site air pollution was perfectly inelastic with respect to price, which allowed them to estimate only a WTP function, as discussed in Section 4.3.2. Tests of this assumption indicated that it may not have been entirely valid, but they argued that alternative procedures did not greatly change their final benefit estimates.

Linear and log-linear forms of the WTP functions were estimated with the log-linear giving the best fit. The pollution coefficient was allowed to vary across three income groups: less than $9,500, between $9,500 and $13,000, and over $13,000 median annual household income. A positive relationship was found between income and WTP. For all groups, willingness to pay for a reduction in NO_x was an increasing function of air pollution. This is the expected direction of the relationship because an increasing willingness to pay for a reduction in NO_x (a positive price) is equivalent to a decreasing willingness to pay for NO_x (a negative price). Harrison and Rubinfeld, as well as the subsequent authors presented here, used the absolute value of the marginal implicit price as the dependent variable in the WTP function rather than the actual negative marginal implicit price.

Benefits Estimates

The Clean Air Act mandated that by 1978 new cars were to be producing 90% less emissions of NO_x, carbon monoxide, and hydrocarbons than in 1970. Since the average life of an automobile is ten years, most of the cars on the road in 1990 will have been produced after 1978. Harrison and Rubinfeld used the NO_x concentrations predicted by the air pollution dispersion model based on expected 1990 automobile emission characteristics to estimate average household benefits of attaining the federal emissions standards. These are given by the formula:

$$AB = \frac{\sum_{i=1}^{n} (HH_i) \int_{NO_x90_i}^{NO_x70_i} W_i \, dNO_{xi}}{r \sum_{i=1}^{n} (HH_i)}$$

where:

AB = average annual benefits per household
HH_i = number of households in tract i
r = the discount rate
NO_x70_i = 1970 NO_x level in tract i
NO_x90_i = 1990 NO_x level in tract i

The integral is the area under the WTP curve for tract i between 1970 NO_x levels and 1990 NO_x levels. When the single WTP function that was estimated for all households and a 10% discount rate were used, this figure was \$83 per year. When the three WTP functions estimated for the different income groups were used, the average benefits were \$93 per year for low-income households and \$71 per year for high-income households, because low-income households tended to live in more polluted areas.

The authors point out that to the extent that the WTP equations for an NO_x reduction reflect damages associated with non-automobile pollution, other than NO_x, the benefit estimate for auto emission controls may be overstated even though the calculations assumed no reduction from non-automobile sources of NO_x. On the other hand, other automobile emissions, such as carbon monoxide, and impacts that may not be reflected in housing prices may not be fully reflected in the NO_x equation, and therefore the true benefits would tend to be understated. The authors did not venture to guess which of these effects would predominate.

Evaluation Comments

The mean marginal implicit price for NO_x and the benefit estimates derived from the WTP functions seem to be quite feasible, but there appears to be a problem with the hedonic price function using TSP. The marginal implicit price function for TSP is given by the first derivative of the hedonic price function with respect to TSP, which evaluated at the mean values of the TSP and the property value variables results in a marginal implicit price of over $1,000,000 for a one mg/hm^3 reduction in TSP. This is an unrealistic result for which there is no obvious explanation.

The authors report that there is evidence of heteroscedasticity in their WTP function. This might be caused by omitted variables. They report that a few housing attributes in addition to air pollution were statistically significant in explaining willingness to pay for a reduction in air pollution. They argue that the benefit estimates were not greatly changed by the inclusion of other housing attributes and therefore used the WTP function with only NO_x and income to derive benefit estimates. However, under different circumstances the influence of other attributes may have a significant effect on benefit estimates and the possibility of complement and/or substitute relationships between air pollution and other housing attributes should be more fully explored.

The use of an air pollution dispersion model to obtain data on air pollution concentrations in each neighborhood increases the researcher's flexibility in choosing the neighborhoods or tracts to be used in the study, because actual monitor station data is usually quite limited. However, the accuracy of the benefit estimates then depends on the accuracy of the dispersion model. Progress is being made in the development of such models, but it may be premature to place much confidence in currently available air pollution dispersion models for urban areas.

6.2.3 The Denver Study

Study Area Description and Data Selection

Bresnock (1980) performed a hedonic price study of property values in Denver County, which is the city center of the Denver SMSA. Denver has a serious air pollution problem, fondly called "the brown cloud," with carbon monoxide (CO), ozone, and TSP frequently exceeding national ambient air quality standards. Approximately 80% of the total air pollutants and over 90% of the CO are believed to come from mobile sources. This study concentrated on CO, which, during the second worst day in 1978, had an 8-hour average concentration mean of 121 part per ten million (pptm) and ranged from 18 pptm to 239 pptm across the study area.

Census tract level 1977 data from the Denver Planning Office, which included average sale prices of owner-occupied homes, and census tract averages of several house structure variables were used. Amenity and accessibility variables used were percentage of land used for transportation, business, and utilities; number of public school children per acre; crime rates on persons and on property; distance to CBD; and access to major streets and highways. Tracts with less than 20% owner occupancy or predominantly nonresidential, open space, or high residential density composition were eliminated, leaving 109 census tracts for the study sample.

The CO data were obtained from a pollution dispersion model developed by Systems Applications, Inc. (SAI) that predicted CO concentrations for each square mile based on monitor station readings and wind patterns on the second worst day in 1978. These grids were then matched to the census tracts in the study sample.

Hedonic Price Function Estimation

Linear and semi-log functional forms were tested, and though the differences were inconclusive, the semi-log form was selected because a nonlinear form was considered theoretically superior. Different exponents for the pollution variable were examined with a value of 2 chosen as providing the best fit. For the values of the estimated coefficients and the range of the pollution variable in this study, this functional form implied that the marginal implicit price of air pollution became an increasingly large negative value as air pollution increased. All the coefficients were significant except those for average square feet of lot size and school children per acre. The final hedonic price function explained 90% of the variation in average property sale prices.

The hedonic price function was tested for market segmentation by separating the sample tracts into a greater than 40% minority and average income less than $12,000 group and a less than 40% minority and average income more than $12,000 group. These two hedonic price functions were found to be significantly different.

At the mean, a one pptm reduction in CO was associated with a $67 increase in property values; however, for the two separate hedonic functions the mean marginal implicit prices for a one pptm reduction of CO were $83 for high-income areas and $79 for low-income areas.

Willingness to Pay Function Estimation

Following the same procedure as Harrison and Rubinfeld, Bresnock assumed supply of residential site air pollution was fixed at all locations. Willingness to pay for a reduction in CO was hypothesized to be a function of CO levels, median family income, number of people over age 65 per acre, percentage of housing financed via conventional loans, autos per capita, percentage change in family income 1970-1977, average number of persons per unit, and average appreciation rate of property value for 1976-1977.

This was a more extensive specification of the WTP function than that used in the other studies, and all the variables were found to significantly influence WTP except number of the elderly and change in income variables. A log-linear functional form was chosen as a better fit than the linear form. This function explained 83% of the variation in willingness to pay, whereas the Boston study's equation explained only 64%.

Benefit Estimates

The Colorado State Implementation Plan (SIP) is hoping to achieve national ambient air quality standards by 1982. Predictions of 1982 CO levels for the same weather conditions as the second worst day in 1978, but with the emission reductions to be achieved by the SIP, were generated by the SAI Denver model. Average annual household benefits from the single WTP function were $258 for this reduction in CO, using a 10% discount rate and assuming a perpetual stream of benefits (see Section 4.3.2). When estimated separately for the two segments, this became $230 for the high-income group and $374 for the low-income group. This was because the low-income group tended to be living in areas of higher pollution, which outweighed the fact that the high-income group was willing to pay more for a given reduction in air pollution.

Evaluation Comments

Probably the most important question concerning the Denver study is the use of CO as the air pollution measure. Carbon monoxide is a colorless and odorless pollutant and although the CO pollution problem in Denver is well publicized it is unlikely that residents are aware of the day-to-day carbon monoxide levels in their particular neighborhoods. The property value approach relies not on awareness of the overall pollution levels in the area but on awareness of neighborhood-to-neighborhood variations in pollution. Pollution that is perceived by residents in the Denver Area is actually a mixture of several individual pollutants produced from several different sources and from chemical reactions in the atmosphere. The author justifies the use of CO as a proxy for air pollution in Denver because it was highly correlated with the coefficient of haze, which is a measure of what people see but which had not been projected for the 1982 plans. CO was also the pollutant that had been most successfuly modeled in the air pollution dispersion models used for this study. Using CO as a proxy for air pollution was therefore a reasonable choice, but it would be interesting to see results of the same procedure using a measure of a pollutant that is more readily noticed by the average person.

There is currently some uncertainty about the accuracy of the air pollution dispersion models such as the one that was used to obtain data on census tract CO levels for this study. These techniques are still being developed, and though improving, are not be entirely reliable for urban pollution dispersion modeling.

Additionally, the author used data for CO levels on one particular day. Most other studies have used an average measure of pollution for the study period, because households are expected to be more concerned with their average exposure to harmful or unpleasant pollution than with their exposure on a particular day. A measure of pollution on a particular day is only appropriate for a hedonic price function for property value if it represents a typical or average pattern of pollution dispersion across the study area.[11]

The specification of the WTP function was more extensive than that of previous studies, and the author reported than there was no evidence of heteroscedasticity. This seems to be an improvement over Harrison and Rubinfeld's WTP equation, although only additional household characteristics and no additional property attributes were included. Some instability in the estimated function, such as the coefficient for autos per capita switching from positive and significant in the linear willingness to pay function to negative and significant in the log-linear form, indicates that more possibilities in the specification of the willingness to pay function need to be explored.

To test for market segmentation the sample was divided into two subgroups--high-income, white and low-income, minority--and a separate hedonic price function was estimted for each. That the coefficients in each of these separate functinos were significantly different from one another was taken as evidence of market segmentation, but the same result could have resulted from an incorrectly specified hedonic price function. As discussed in Section 4.3.2, if the correct functional form can be specified there would be no need to estimate separate hedonic price functions for each subgroup unless the structure of supply and demand were different in each subgroup. If they were different, this would imply the need for separate and unique functional specifications of both funcational form and explanatory variables for each subgroup.

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[11] The author has later explained that the geographical variation in CO on the second maximum day closely matched the pattern of annual average TSP across the study area, indicating that the measure of CO on the second maximum day was an appropriate proxy for average pattern of air pollution for this study. (Bresnock 1981)

6.2.4 The South Coast Air Basin Study

Brookshire, Thayer, Schulze, and d'Arge (1979, 1980) used the South Coast Air Basin (SCAB) of Southern California to obtain and compare the results of a bidding method survey and property value study for the same area.

Study Area Description and Data Selection

Southern California has a well defined and well publicized air pollution problem. Both mobile and stationary sources are responsible, and national primary ambient air quality standards are frequently exceeded. Photochemical smog, largely ozone, and its precursors, NO_x and hydrocarbons, are the predominant pollutants. The SCAB study used both NO_2 and TSP measures. Annual averages of these pollutants for 1975 ranged from 6.2 to 13.0 pphm and 67 to 130 $\mu g/m^3$, respectively, across the study area. That California has led the nation in automobile emission standards was considered evidence that residents are aware of the air pollution damages and are willing to incur some costs to reduce the problem.

Household level data on property sales prices for owner-occupied single-family residences and other characteristics of the property were obtained from Market Data Center in Los Angeles for homes sold between January 1977 and March 1978. Data on property taxes, public expenditures, crime rates, school quality, weighted distances to the major employment centers, and the distance to the beach were used to represent the accessibility and amenities of each community. Community boundaries did not always coincide with census tract boundaries, with communities sometimes covering part of one or two tracts. Census data were adjusted to match community boundaries.

Pollution measures for NO_2 and TSP were obtained from the California Air Resources Board. The 1975 average of the daily hourly average maximum for each pollutant was used. These were interpolated from data obtained from monitoring stations so that the locations of the stations influenced the selection of the community study sample.

Seven community pairs were selected to minimize differences other than air quality. Communities were rated as having poor, fair, or good air quality, with approximately a 25%-30% difference in average pollution concentrations between each category. They were the first to use this matched pairs technique, as described in Section 4.3.3, to remove some of the non air quality differences between properties. The study of a small number of paired communities or tracts was possible because the household level data provided a large number of observations within each community or tract. It is not possible to be quite so selective when using census tract averages. All 719 sales of owner-occupied single-family residences in each of the 14 selected communities during January 1977 to March 1978 made up the final study sample.

Before a hedonic price function was estimated the authors examined the property value differences between the matched communities. If the communities were perfectly identical except for air pollution, the property value differences would reveal approximately the same information as a linear hedonic price function; that is, how much households are paying to avoid each additional unit of air pollution. However, as expected, the linear and nonlinear hedonic price functions that were subsequently estimated provided considerably smaller estimates of the marginal implicit price of air pollution, indicating that the communities were not perfectly matched.

Hedonic Price Function Estimation

A hedonic price function was estimated for each pollution variable. Both had the expected negative coefficients and were statistically significant. Both equations explain 88% of the variation in property prices. Linear and semi-log exponential functional forms were tested with the latter selected as the better fit. The estimated exponent for the NO_2 variable and for the TSP variable in separate hedonic price functions was 2. For the range of the pollution variables in this study both of the functions imply that the marginal implicit price of air pollution became an increasingly large negative value as air pollution increased. Each one pphm reduction in NO_2 was associated with an increase in property values of $2,010 at the mean value of NO_2 and the other variables. The TSP equation implied a marginal implicit price of approximately $300 per $\mu g/m^3$ at the mean value of TSP and the other variables.[12]

Because the community sample used for this property value study did not match the survey sample that was eventually used, this hedonic price function was later re-estimated for six of the seven community pairs. The results of both estimations are reported here because the authors did not estimate a WTP function the second time. They decided that they could not accept the assumptions implicit in this methodology for estimating WTP in their comparison of the results of the property value and bidding method approaches.

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[12] The price for TSP was not reported by the authors but was roughly estimated using the reported coefficient and assuming a mean property value of $100,000 and a mean TSP level of 100 $\mu g/m^3$.

The most important difference in results was that the best fitting functional form for the second hedonic price function was that in which the pollution variables were entered in logarithmic form rather than squared. This implies that the marginal implicit price for air pollution became an increasingly small negative as air pollution increased, which was not consistent with the first hedonic price function. From this second hedonic price function, the mean marginal implicit price for a change from poor to fair air quality was \$46 per month, and the mean marginal implicit price for a change from fair to good air quality was \$59 per month. These are roughly equivalent to saying that a 1 pphm reduction in NO_2 will increase property values by \$1,840 and \$2,360, respectively, and a one $\mu g/m^3$ reduction in TSP will increase property values by \$184 and \$236, respectively.[13] These are reasonably close to the marginal implicit prices obtained by the first hedonic price funtion.

WTP Pay Function Estimation

Willingness to pay for a reduction in air pollution was estimated for NO_2 and for TSP from the first hedonic price function. Supply of air pollution was assumed to be fixed at each location, and community level data were used because household level income data were not available. Willingness to pay for a reduction in air pollution was hypothesized to be a function of NO_2 or TSP levels and community average household incomes. As expected, WTP was found to increase as pollution increased and as incomes increased. Similar results were obtained for both linear and log-linear forms and for both pollutants.

Benefit Estimates

From the log-linear WTP function, average household benefits for an improvement from poor to fair or from fair to good air quality, both approximately 25%-30% reductions in air pollution, were estimated at \$44 per month from the NO_2 equation and \$49 per month from the TSP equation using a discount rate of about 10%. This means that the average annual benefits of reducing air pollution by 25%-30% would be between \$528 and \$588 per household.

Evaluation Comments

An important question regarding the results of the SCAB study concerns the difference in best fitting functional form obtained after the sample was reduced to twelve communities. The community pair, Whittier and Orange, was dropped because bidding method surveys were not conducted in those communities. This reduced the number of properties from 719 to 634, which is still a more than adequate number for which to estimate a hedonic price function. The authors report that with the same functional form, semi-log exponential using the log of property values and air pollution squared, the air pollution coefficient was no longer statistically significant. The air pollution coefficient became significant when the air pollution variable was entered in log form rather than squared.

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[13] These capitalized prices were computed from the reported monthly prices assuming a 10% discount rate and a 3 pphm NO_2 or a 30 $\mu g/m^3$ TSP change from poor to fair and from fair to good air quality.

Such instability caused by a fairly minor change in the sample is disconcerting. Judging from the average property values and characteristics levels reported for Whittier and Orange these communities fell between the upper and lower extremes of these variables in the sample. The difference between the two functional forms is significant in that the first implied a negatively sloping marginal implicit price function for the range of the variables in the sample whereas the second implied a positively sloping marginal implicit price function. In both cases the authors report that the results are not very much different than those obtained with a linear form, but they offer no explanation of the apparent instability of the nonlinear functional form. It might be reasonable to obtain such variability across different urban areas, but not across slight modifications of the sample within one urban area.

It is interesting to note that the property value differentials obtained from the second hedonic price function, \$46 and \$59 per month for a 25%-30% reduction in NO_2, only slightly exceed the average household benefits derived from the WTP function estimated from the first hedonic price function (\$42 to \$44 per month) for the same reduction in NO_2. These both significantly exceed the average stated willingness to pay obtained from the bidding method survey, \$15 and \$20 per month for the same reduction in air pollution of 25%-30% in fair and poor areas. Which, if any, of these estimates is closest to the true value that households place on such an improvement in air quality is not known.

This study has made an important contribution with the development of the matched pairs technique for selecting property values. Although alone it is of limited usefulness, as discussed in Section 4.3.3, in conjunction with the estimation of a hedonic price function it may help to eliminate some of the non-quantifiable differences between properties. As previously mentioned, this selection process was possible because of the availability of household level data.

6.2.5 The San Francisco Bay Area Study

Study Area Description and Data Selection

Loehman, Boldt, and Chaikin (1980) studied the San Francisco Bay area (SFBA) in a replication of the SCAB study. Air pollution is less severe in the San Francisco area than in Southern California, although photochemical oxidants are the primary pollutants in both areas. The results indicate that benefit estimates are not directly transferable, but this question needs further study.

Household level data were obtained from the Market Data Center for owner-occupied single-family properties sold during 1978. Household, census tract, and city level data sets were developed so that the effects of different levels of aggregation could be examined.

Data for NO_2, TSP, ozone and the Pollution Standards Index (PSI) were used. A unique ozone index was developed by multiplying the number of days on which the national primary standard was exceeded times the average daily maximum for July through September for 1979 and 1978. This variable included information about ozone concentration maximums and frequency of occurrence. Also, the PSI was adjusted by multiplying the 1977-78 average PSI value times the number of days that were not rated good.

Tracts with no property sales or with bad or missing data were eliminated from the sample. Also, tracts dominated by unincorporated areas, institutional facilities, very low or very high residential density, and low owner occupancy were eliminated. The remaining tracts represented six tract types which were subject to stratified sampling proportional to population in each group. Forty-two tracts were thus chosen, and the household sample consisted of all houses sold in these tracts. The household sample included 2,570 observations.

Hedonic Price Function Estimation

The first hedonic price function estimated was identical to the one estimated for the SCAB study, except that initially, the major amenity variable was changed from the distance to the beach to elevation, because view was considered more important than the accessibility to the beach in the San Francisco area. The results of the otherwise similar hedonic price function indicated that it explained about 10% less of the variation in property prices than it had explained in the SCAB study. Also, the NO_2 coefficient was significantly positive, but this was attributed to the fact that NO_2 is not a problem pollutant in the SFBA. TSP and the ozone measures had significantly negative coefficients, as expected, yet PSI was insignificant.

Concluding that the hedonic price function specification has to be adapted to each study area, the researchers specified a new function. A great deal of data were available, and due to the typically high correlations between variables, factor analysis was applied to group the variables into factors within which the correlation was maximized and between which it was minimized. Then a few variables from each of the groups were chosen as proxies for each group. The new specification explained 87% of the variation in property prices.

The logarithmic form of property prices was used as the dependent variable. The pollution variable and other variables expected to have a negative influence on property prices were squared while the others were entered in logarithmic form. The authors explain that this allowed the WTP functions for the "bad" and "good" attributes to have the expected slopes.

The East Bay and West Bay areas were found to produce significantly different hedonic price functions. These two areas are separated by the San Francisco Bay, and over 80% of the work trips originating in each area are made to destinations within the same area. The ozone index and the adjusted PSI variable were selected as the air pollution proxies for the final hedonic price functions. Different results were obtained when the tract and city level data were used, indicating that the level of aggregation will make a difference.

Willingness to Pay Function Estimation

Household level data on incomes and age of buyer were obtained from savings and loan data, and to ensure consistency, the hedonic price function was re-estimated with the savings and loan property price and attributes data. Willingness to pay for a reduction in air pollution was then estimated as a function of ozone, household income, and age of buyer. A log-linear functional form was used for the WTP function. For comparison, WTP was also estimated with city level data, because none of the other studies have used household level data. In both cases, willingness to pay for a reduction in air pollution was found to increase with pollution levels and with income, as expected.

Previous studies have used the actual property value to derive the marginal implicit price of air pollution that is taken as an observation of the household's WTP, but this study used the property value predicted by the estimated hedonic price function given each property's attributes. For example, with a semi-log exponetial hedonic price function:

$$\log PVi = a + bAPi^2$$

where:

PVi = actual property value of residence i

APi = actual air pollution at residence i

The marginal implicit price function is given by:

$$\frac{dPVi}{dApi} = 2b \cdot APi \cdot PVi$$

Most authors have used the estimated value of the coefficient, $\hat{b}$, and the actual air pollution and property value at residence i to compute the marginal implicit price of air pollution at residence i. However, the authors of this study chose to compute the predicted property value at location i, $P\hat{V}i$, from the estimated hedonic price function given $\hat{b}$ and the actual level of AQi. The PVi and $\hat{b}$ were used along with AQi to compute the marginal implicit price of air pollution at residence i.

Benefit Estimates

The preliminary results of this study indicated that annual benefit estimates derived from the household level WTP function for a 30% decrease in the ozone index ranged from \$.13 to \$436.37 per household, the higher figures in the more polluted areas. From the city level data, average annual benefits of a 30% decrease in the ozone index were found to range from \$.12 to \$337.10 per household with an overall average of \$82 per household. This average benefit figure for a 30% reduction in pollution is smaller than that obtained by the SCAB study, but pollution levels are higher in Southern California, and the benefit estimates are based on a different pollution measure.

Evaluation Comments[14]

This study provides the most thorough examination of potentially significant property attributes of any of the studies discussed here. This is important because air pollution is a relatively unimportant attribute in determining property values. Therefore the more carefully all significant attributes are identified the more confidence can be placed on the influence attributed to air pollution.

One problem with the explanation of the hedonic price function specification for this study is that vacancy rates, percentage of new houses, and percentage of land available for development were added as supply side variables. These variables could possibly be interpreted as neighborhood characteristics, but the inclusion of variables other than attributes of the good in the hedonic price function contradicts the theory of hedonic prices as presented by Griliches (1971) and Rosen (1974). The hedonic price function is supposed to separate the price of the property into the amounts attributable to each attribute of the property. Supplier and household characteristics enter the suppliers' offer and households' bid curves. The interaction of these functions results in the hedonic prices that are observed in the market, but as the hedonic price theory is currently applied, the supplier and household characteristics do not directly enter the hedonic price function. (See Sections 4.3.1 and 4.3.2.)

The functional form for the hedonic price function was selected in order to obtain the expected negatively sloped WTP for "good" attributes and positively sloped WTP for a reduction in "bad" attributes. This reasoning makes sense, but it is not the appropriate justification for the selection of functional form. The appropriate functional form for the hedonic price function is one that does not constrain the slope of the marginal implicit price with respect to the quantity of an attribute, not one that constrains this slope to be either positive or negative. (See Section 4.3.2.) In fact, the functional form that was selected does allow the marginal implicit price functions for both bad attributes and good attributes to have either positive or negative slopes as would not be the case if all attributes were entered in log form or if all attributes were entered squared. However, there are other more general functional forms, such as Box-Cox, that would also allow such flexibility.

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[14] This review is based on a preliminary report of the study results.

The authors argue that it is preferable to use the estimated property value rather than the actual property value to compute the marginal implicit price of air pollution at each residence due to the simultaneity of the determination of the hedonic price function and the marginal implicit price function. However, the marginal implicit price function is mathematically derived from and entirely determined by the hedonic price function. They are not simultaneous equations in the usual sense. It may also be that statistical bias results from the use of the estimated value of PVi in this functional form.[15] Their procedure does not appear to be an improvement over the use of actual property values to compute marginal implicit prices.

The air pollution measures used were average concentrations times the number of days that exceeded certain levels. Though these measures make sense in that they consider both concentration levels and frequency of occurrence, they make the results of this study difficult to compare with national air quality standards and with the results used by other studies.

6.2.6 Comparison and Review

It is extremely difficult to compare the numerical results of these studies, because they cover different study areas with different air pollution measures; however, it is striking that all of the studies have found that a measure reflecting levels of one or more of the problematic air pollutants in each study area has a statistically significant negative relationship with property values. This is strong evidence that people are willing to pay higher prices for homes in locations with better air quality and that the results of these preferences are reflected in observable differences in property values. The Boston study found that at mean values of the NO_x measure and other variables in the hedonic price function, a 1 pphm reduction in NO_x was associated with a $1,613 increase in residential property values in 1970 dollars. The SCAB study found that a reduction in NO_2 from poor to fair conditions, an approximately 3 pphm reduction, was associated with an average increase in property values of approximately $5,520; and a reduction in NO_2 from fair to good conditions, also about a 3 pphm reduction, was associated with an approximately $7,080 increase in property values in 1977-1978 dollars.[16] These results are very much in the same vicinity. The SCAB study also obtained mean marginal implicit prices of from $184 to $300 per $\mu g/m^3$ TSP, while the Washington DC study obtained $69 per $\mu g/m^3$ TSP in 1970 dollars.

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[15] V. Kerry Smith has suggested that due to Jensen's inequality, which says that the expected value of a convex function is not equal to the convex function of the expected value (see Mood, Graybill and Boes 1974), $\hat{PVi}$ will be a biased estimate of E(PVi).

Table 6.10 lists all the variables used in the hedonic price functions in each study. They vary from one study to the next due to different data availability and different study area characteristics. Because each of these studies has found some variables that significantly influence property values which have not been used in some of the other studies, it is unlikely that early studies that examined a limited number of variables specified the hedonic price function entirely accurately. All of the studies have explained 80-90% of the variation in property values, but air pollution is a small influence compared with many other variables, and therefore other minor influences that have been overlooked may be affecting the influence attributed to air pollution if they are correlated with air pollution.

More work needs to be done to verify that no important location-specific amenities that may be correlated with air pollution have been overlooked in these studies. In particular these studies have looked at school quality; crime rates; accessibility to major scenic and recreational amenities, such as rivers or the ocean; access to employment; land use; and access to the CBD; but we do not know if these and air quality are the only neighborhood amenities that need to be considered. It is possible that proximity to parks, availability of public transportation, proximity to grocery stores, and many other considerations are as or more important as air quality in the household's residential location decision. The SFBA study has explored many more possible influences than the other studies and has found several of them to be significant.

Table 6.11 summarizes several important aspects of each of the studies including pollution measures used, mean marginal implicit prices, and WTP estimates for the scenario considered by the study.

Evidence concerning the appropriate functional form for the hedonic price function is quite inconclusive. The same forms were not tested in each case, but some studies found that the best fitting form was one that implies that the marginal implicit price of air pollution increases as air pollution increases, while others found the opposite. Because the marginal implicit price function is determined by the interaction of supply and demand for air pollution, there is no reason to expect it to be either positively or negatively sloped, or even to expect it to have the same slope in all study areas, but the sometimes contradictory and frequently inconclusive results are somewhat disconcerting. Harrison and Rubinfeld tested for and found that benefit estimates were sensitive

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[16] These figures were estimated from the reported monthly rent differentials assuming a 10% discount rate and a perpetual stream of benefits.

Table 6.10: Variables in the Hedonic Price Function

	Washington D.C.	Boston	Denver	SCAB	SFBA
Accessibility of Neighborhood					
distance to CBD	X		X		
distance/time to employment	X	X		X	X
access to highways		X	X		
distance to beach				X	
Environmental Characteristics of Neighborhood					
carbon monoxide			X		
nitrogen oxides		X		X	X
suspended particulates	X	X		X	X
ozone	X				X
temperature					X
pollution standards index					X
House Characteristics					
% over 30 years old	X	X			
age of house				X	X
% new houses					X
house condition index					X
lot size	X		X		X
living area			X	X	X
rooms/unit	X	X			
# bedrooms			X		
# bathrooms			X	X	X
sales date				X	X
pool				X	X
fireplace				X	X
central air-conditioning	X				
no toilet	X				
parking on site					X
persons/unit					X

Table 6.10 (Continued)

	Washington D.C.	Boston	Denver	SCAB	SFBA
Socioeconomic Neighborhood Characteristics					
% owner occupied			X		
% black	X	X	X		
% Spanish			X		
% lower status		X			
populaton density			X	X	X
median years of school					X
% zoned large lots		X			
% below poverty level					X
% white				X	
housing density				X	
Taxes and Public Services in Neighborhood					
public safety expenditures				X	
public school children/acre			X		
school expenditures/student	X				
school test scores				X	X
student/teacher ratio		X			
property tax rates	X	X			
composite tax rate				X	X
Neighborhood Amenities and Disamenities					
% transportation, commercial, utilities acreage			X		
% business, commercial, industrial acreage					X
% non-retail business acreage		X			
% available for development					X
% precluded from development					X
vacancy rate					X
crime rate	X	X	X	X	X
adjacent to river	X	X			
view present					X
elevation					X
slope					X
Property Values					
median census tract market value	X	X			
average census tract sale price			X		
individual property sale price				X	X

Table 6.11

Marginal Implicit Prices and Willingness to Pay Measures in Property Value Studies[a]

Study (Time)	Hedonic Price Functional Forms Examined[d]	Pollutant Measures	Magnitude of Pollutant Examined Mean; Range (standard deviation)	Marginal Implicit Price at Means	Willingness To Pay Scenario	Average Annual Willingness Pay Per Household
Washington, D.C. (1969-70 Data)	Linear, Semi-Log, Inverse Semi-Log, Log-Linear*	TSP ($\mu g/m^3$) oxidant (.001 ppm)	N.R.	$\$69/\mu g/m^3$ $15/.001 ppm	None reported.	
Boston (1970 Data)	Linear, Semi-Log, Semi-Log Exponential*	NO (pphm) TSP (mg/hm^3)	6.31; 3-9 (1.16) 5.55; N.R. (1.50)	$1,613/pphm $\$1,000,000^b/mg/hm$	Reduce automobile NO emission from 1970 levels to expected 1990 levels based upon new automobile emissions standards.	$83/year/household ($71 high income; $93 low income)
Denver (1977-78 Data)	Linear, Semi-Log Semi-log Exponential*	CO pptm	121; 18-239 (55.5)	$67-83/pptm	SIP to meet National Ambient Air Quality Standards by 1982.	$258/year/household ($230 high income; $374 low income)
SCAB[c] (1975-78 Data)	Linear, Semi-Log, Semi-Log Expoential*	TSP ($\mu g/m^3$) NO (pphm)	N.R.; 6.2-13.0 N.R.; 67-130	$\$300^b/\mu g/m^3$ $2,010/pphm	25-30% improvement in region-wide air quality.	$528-$588/year/household
	Linear, Semi-Log, Exponential, Log-Linear*	Same	Same	$\$184-\$236^b/\mu g/m^3$ $\$1,840-\$2,360^b/pphm$		Not estimated
SFBA (1979-80 Data)	Semi-Log Exponential*	Ozone Index PSI Adjusted	90; N.R. (81.6) 15.9; N.R. (9.1)	N.R.	30% decrease in ozone index region-wide.	$82/year/household

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N.R. = Not Reported.

[a] Results based upon those presented by authors. Conversion factors are: $1 \mu g/m^3 = 1 mg/hm^3$; 1 ppm = 10 pptm = 100 pphm.

[b] Not reported but calculated from results with assumptions.

[c] Results reported in the upper and lower sections correspond to the first and second hedonic price functions that were estimated for SCAB.

[d] Functional form of hedonic price function used for benefit estimation denoted by *.

to the use of different functional forms of the hedonic price function. The uncertainty about the correct functional form of the hedonic price function indicates that future property value studies should be careful to test alternative forms and check the sensitivity of their benefit estimates to the form chosen.

Table 6.12: WTP Elasticities

	Pollution	Income
Washington D. C.[a]	+.81	+.80
Boston	+.90 to .97	+.80
Denver	+.84 to .98	+.63 to .90
SCAB	+.87	+1.15
SFBA	+1.00	+.28

[a] Nelson uses 1/p the WTP function, but in the log-linear form this only changes the sign of the elasticity.

$$\log WTP = \log a + b \log 1/p + c \log Y$$
$$= \log a + b \log 1 - b \log p + c \log Y$$

Table 6.12 reports the air pollution elasticity as defined by the percentage change in willingness to pay for a reduction in air pollution with respect to a one percent change in air pollution, and income elasticity as defined by the percentage change in willingness to pay for a reduction in air pollution with respect to a one percent change in income. In the log-linear form of the WTP functions these are given by the estimated coefficients of the pollution and income variables.[17] As shown in Table 6.12, the estimates of elasticity of willingness to pay for a reduction in air pollution with respect to air pollution are all somewhat less than or equal to 1. This means that a 10% increase in pollution would be associated with a somewhat less than 10% increase in willingness to pay for a reduction in air pollution.

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[17] The WTP elasticities, as defined for Table 6.12, are not reported in all of the studies. Some of the studies reported elasticities as if the WTP function were a demand function. When a demand curve is estimated with price as the dependent variable, i.e., when willingness to pay is estimated, the dependent variable must be changed to quantity to obtain the usual elasticities.

(1) $\log PRICE = \log a + b \log QUANTITY + c \log INCOME$

can be rewritten

(2) $\log QUANTITY = \log a^* - 1/b \log PRICE + c/b \log INCOME$

When equation 1 is estimated, the usual price elasticity, % ΔQUANTITY/ % ΔPRICE, is given by -1/b, and the usual income elasticity, % ΔQUANTITY/ % ΔINCOME, is given by c/b. However, these are not very useful in the analysis of the willingness to pay for a public good, because the consumer does not have the flexibility in choice of what quantity to consume that he has for private goods.

The estimated income elasticities of WTP vary somewhat more. All the studies but one found that willingness to pay for a reduction in pollution is income inelastic, which means that a 10% increase in income would cause less than a 10% increase in WTP. The one that is most divergent is from the SFBA study, the only one that used household level data in the WTP function. The Denver study was the only one to estimate different income elasticities for different income groups and found that the high-income group had the higher income elasticity. This is consistent with the suggestion that air quality is a luxury good, because lower-income households would be willing to spend less of a 10% increase in their incomes on air pollution reduction than would higher income households.

The consistency of the results of the estimation of elasticities of willingness to pay for a reduction in air pollution should, however, be viewed with caution. It may be more the result of the consistency of the estimation procedure than of the similarity of WTP across areas. Four out of five of these are based on a hedonic price function estimated with the same functional form. Also, the growing skepticism about the information obtained in the second step of this procedure--specifically, when the derivative of the hedonic price function with respect to air pollution is used as the dependent variable in the WTP function--indicates that much more work in this area needs to be done. The somewhat comparable mean marginal implicit prices obtained by different studies for the same pollutant is promising. The one direct test of transferability (the SFBA study) indicated the hedonic price function for property values was definitely not transferable and that, not surprisingly, willingness to pay to reduce air pollution will be different when air pollution conditions are different.

6.3 Comparison of Property Value and Bidding Method Benefit Measures

The measures of aggregate benefits to be achieved from emission controls may be influenced by the selection of the property value or bidding approaches. To date, the bidding approaches and other non-market approaches give the only reliable estimates of visibility-related benefits in Class I or recreation areas. In urban areas both approaches may be applied; yet, in general, the question still remains, Do the benefit estimation methods yield comparable results?

It is extremely difficult to compare the results of the bidding method studies and the property value studies, because the economic good, visibility or air quality, is defined differently in each type of study. In several bidding studies the respondents were asked to value nebulously defined best to worst cases. In other bidding studies more concrete definitions of visual range reduction in kilometers were used. Property value studies have used pollutant concentrations. This causes a problem, since there is a limited ability to compare the visual effects of parts per million of ozone or SO_2 to kilometers reduction in visual range and most especially to the public's perceptions of these reductions.

Given the difficulty in making comparisons, the benefit estimates derived from the two approaches do exhibit a degree of comparability. Because each of the studies uses different measures and levels of air pollution, we group them into generalized worst, best and moderate conditions for comparison. Several of the bidding method studies obtained annual benefit estimates for a comparison of worst and best scenarios of about $80 per household for non-metropolitan areas. The SCAB study bidding method study obtained larger estimates of about $250 per household per year for comparisons of worst to best, of which about $80 was bid for the visibility aesthetics component and the rest for health-related changes.

Benefits from property value studies are difficult to compare because the pollution measures and proposed improvements greatly vary across studies. In the more severely polluted areas of Denver and Southern California, values of around $250 to $500 per household were estimated for 30% to 50% improvements in air quality. As demonstrated in the SCAB bidding method study, a significant portion of these benefits may be health related, so that the aesthetic portion is likely to be in the vicinity of $100 to $200 per household per year, which is somewhat larger than the bidding method results. A comparable result of most bidding method and hedonic property value studies is that the measured willingness to pay for visibility changes was consistently found to be inelastic with respect to income.

Because of differences in time periods, pollutant measures, location, etc., more exacting comparison or statistical tests across most studies would be spurious; however, the SCAB study simultaneously applied both the bidding method and hedonic property value approaches for the specific purpose of comparing the results. The SFBA study is replicating this experiment, but their bidding method study results are not yet available.

The results of the SCAB comparison for an approximately 30% region-wide improvement in air quality yielded bidding method estimates up to 62% as large as of the property value estimates. An average bid of $312 per household per year as opposed to an average WTP derived from the property value study of $504 per year was probably the smallest difference in results between the two approaches.

Results varied greatly with different functional forms for the property values study and with different analysis techniques for the survey, with the bidding method results tending to be significantly smaller but within the same order of magnitude as the property value results. However, in Brookshire et al. (1980) the authors revised this comparison due to their lack of confidence in the procedure for estimating WTP functions from the hedonic price function for property values. (See Section 4.3.2.) As an alternative, the authors hypothesize that property value differences will exceed the true WTP for a given improvement in air quality as was illustrated in Figure 4.1. To test this hypothesis they re-estimated the hedonic price function for property values to more closely match the community sample used for the bidding method survey and from this equation computed the property value difference associated with an approximately 30% reduction in air pollution. The average property value differences were $46 to $59 per month for a comparable improvement in air quality. The bids then did not contradict the hypothesis that true WTP would be less than the property value differences. A more rigorous test for comparing the two approaches will require additional research on the estimation of reliable WTP for air quality functions from property values.

6.4 Visibility Benefits in Benefit-Cost Analysis

The important question for visibility benefit analysis is, Are these aesthetic benefits of a sufficient magnitude, relative to costs, to be influential in a benefit-cost analysis of emissions control? A complete comparison of benefits and costs would be a study unto itself and has not been the focus of this guidebook. Further, it is especially difficult to compare benefits and cost measures from different studies that do not evaluate the same rate and type of emission control. Nevertheless, the aggregate benefit measures from case studies just reviewed may be roughly compared with estimates of control costs to answer the above question.

One source of estimated coal-fired electric-generating power plant control costs is provided by ICF Inc. (1980). This effort identified individual power plants that may have been required to install additional emission control devices to meet EPA requirements regulating visibility impacts in Class I areas, and calculated the required reduction in emissions and costs of control. Up to 12 plants were identified that may have had to install additional emission controls based upon several criteria of maximum allowable visibility impacts in neighboring mandatory Class I Federal areas potentially attributable to the plants.

Subsequent EPA interpretations of the regulations and analysis determined that only one plant (the Four Corners plant) would need to undertake additional control efforts to meet the regulations and that such efforts were already planned in the New Mexico State Implementation Plan (EPA 1981). With this caveat in mind, the ICF estimates of potential control costs for several coal-fired electric-generating plants in the Southwest may be compared with prior benefit studies in the Southwest to address our question. An additional caveat is that the comparisons will be very rough because none of the conditions or impact areas exactly correspond across the benefit and cost studies. The Grand Canyon/Southwest Parks study was to address the issue of comparative costs and benefits but, is not yet available.

ICF identified five power plants in the Southwest potentially impacting visibility in neighboring mandatory Class I Federal areas beyond the defined critical levels. Two of these are in the Four Corners area and affect Mesa Verde National Park (see Table 6.13). Degraded visibility is said to occur when either visual range is reduced by more than 5% or discoloration is greater than 5% (are measured by a blue/red ratio) from

TABLE 6.13

COSTS OF CONTROLLING VISIBILITY IMPACTS IN CLASS I AREAS IN THE SOUTHWEST

Source	State	Affected Class I Area	Distance to Class I Area	Current Worst Case Visual Range Reduction	Capital Cost of Controlling Emission That Affect Visual Range* (million)	Current Worst Case Blue/Red Ratio	Capital Cost of Controlling Emission That Affect Discoloration** (million)
Navajo	Arizona	Grand Canyon	97.7 km	-----	NR	.825	$44.4
Four Corners	New Mexico	Mesa Verde	62.7 km	5.75%	$57.5	.850	45.1
Mohave	Nevada	Joshua Tree	183.0 km	-----	NR	.915	41.8
Comanche	Colorado	Rocky Mountains	82.0 km	-----	NR	.930	14.3
Hayden	Colorado	Flat Tops	64.0 km	-----	NR	.930	10.5
San Juan	New Mexico	Mesa Verde	49.8 km	-----	NR	.940	8.6

Source: ICF Inc. 1980, see also EPA (1981) for analysis and discussion.

*Estimated costs of controlling worst case visual range reduction in affected Class I area to 5 percent. Costs based upon controlling SO_2 emissions using a combination of scubbers, changes in electrostatic precipitators and changes in coal type.

**Estimated costs of controlling worst case plume related blue/red discoloration ratio as close to 95 percent as presently obtainable. Costs based upon controlling NO_2 emission by installing over-fire or curtain air ports over or around the boiler burner nozzle and installation of low-NO_x burners.

man-made sources. The estimated capital costs of controlling emissions so that these plants do not exceed these standards in Class I areas range from \$8.6 million at the San Juan plant to \$102.6 million in the Four Corners plant (columns 6 and 8 in Table 6.11), with a maximum impact on utility rates of 3.1% (see ICF 1980, page 5-3). EPA subsequently determined that, at the present time, NO_x emissions cannot be reduced to achieve a substantial improvement in visibility and is planning to delay imposition of NO_x controls "until such time as more effective with respect to visibility, controls are available" (EPA, 1981).

The ICF estimated costs of control for plants in the Southwest to meet the above criteria exceed the aggregate visibility benefit measures (reported in Table 6.6) for both the Four Corners and Farmington benefit studies conducted in the same area. These differences appear even greater considering that the ICF estimated control costs appear to be for much smaller changes in air quality than those ranging from 3.3% to over 100% in these benefit studies.

Upon closer examination these benefit-cost discrepancies are not so great. First, small changes in air quality at distant national parks may also result in large changes in air quality in the communities and other recreation sites (non-Class I areas) much closer to the emission sources and examined by the benefit studies. Second, most all aggregate benefit measures reported for the two Four Corners studies are for only a portion (10-15%) of the areas impacted by changes in emission controls. Further, these studies principally examined visibility aesthetic related activity values. Initial unreleased results of the Grand Canyon/ Southwest Parks study suggest preservation values may exceed activity values. Therefore, the benefits reported are only a portion of the benefits received for a portion of the impacted population.

Accounting for these factors it is possible that visibility aesthetics benefits of control exceed the costs of control. The estimation and addition of health, agriculture and materials damage benefits would further support the probability that benefits may exceed the costs of control. Clearly, these comparisons are very rough, but they do suggest that visibility benefits are of a substantial magnitude to significantly influence a benefit-cost determination of optimal levels of emissions control. This should provide a strong incentive to push forward in considering and measuring visibility benefits, more carefully related to proposed changes in air quality, when making possible decisions on the appropriate level of emissions control and air quality in the southwest.

The large benefit measures obtained for urban areas also suggests that air quality related aesthetics and health benefits are substantial and that more work is needed to specifically relate these benefits to the costs of control to help determine the optimal level of air quality control in these locations as well as in national parks.

6.5 Applicability of Benefit Estimation Techniques for Prescribed Burning

Analysis of benefits from air pollution control has typically been concerned with continuous or frequent emissions from point sources of pollution, such as power plants and smelters, or from multiple sources, such as with urban and regional haze. Prescribed burning, which has the temporary side effect of producing airborne pollutants and visual degradation, may also be affected by Clean Air Act regulations because it is a humanly induced (anthropogenic) source of pollution that sometimes occurs in or near mandatory Class I Federal areas. Prescribed burning is sometimes viewed as a unique issue with regard to air quality regulations and one for which the usual analysis does not apply because it causes pollution infrequently and has many beneficial results. However, from an economics perspective, prescribed burning may be analyzed in the same benefit-cost framework used to analyze other anthropogenic sources of visibility degradation.

Prescribed burning is the land management tool of burning an area under controlled conditions for forestry and wildlife management, hazard reduction, grazing and other land management objectives. It is most widely used in timber producing areas to eliminate forest residue left from harvesting operations that would be fuel for high intensity wildfires, to remove underbrush before harvesting, and to protect the habitat of the trees for future harvest. Alternatives include mechanical treatment, chemical treatment, or changed harvesting systems that leave less residue or remove underbrush. Prescribed burning is also used in wilderness and other forest areas to maintain the natural ecosystems. Such prescribed burning produces benefits similar to those of natural wildfires by maintaining the normal wildlife habitat without some of the more damaging effects of uncontrolled wildfires. An alternative that is sometimes used is to allow naturally ignited fires to burn under controlled conditions. There are no other currently documented practical alternatives to prescribed burning for maintaining natural ecosystems (EPA 1979).

A benefit-cost analysis of prescribed burning would help in determining that amount of burning which would be economically optimal. Essentially the same procedure would be used as for deciding the amount of pollution to be allowed from a power plant. This would be to measure the gains in consumer and producer surplus for those who benefit from prescribed burning and the losses in consumer and producer surplus for those who incur damages. Cramer and Pickford (1973) summarize this tradeoff for prescribed burning.

> The idea of permitting open burning of unwanted forest residue, thereby placing great amounts of combustion products in the air, may be unacceptable to a lot of people. But permitting these residues to accumulate--thereby inhibiting the reproduction of needed trees and at the same time increasing the risk of a severely damaging fire or of a smoke episode at some chance time--

> is also quite unacceptable. Accomplishing the residue removal job by methods other than burning may also have environmental and economic consequences that are unacceptable to a lot of people. So we must examine the possibility that the carefully regulated use of fire may be less unacceptable than other alternatives in some circumstances. (Page 239.)

There are several specific costs and benefits associated with prescribed burning that must be considered in a benefit-cost analysis. Among the costs are the operational costs of setting, monitoring and controlling the burn; the temporary visual aesthetic impacts; the temporary loss of land for recreation and wildlife in cases where the area was previously available for these purposes; and possibly some health impacts from the smoke. An important benefit of prescribed burning is the removal of forest residue to reduce the risks of substantial damage due to periodic uncontrolled wildfires upon air quality, recreation, wildlife and commercial/private use of the affected lands. Additional benefits include the reduction of underbrush, the maintenance of the natural ecosystem, and the maintenance of a beneficial environment for future timber harvesting and for wildlife. A complete analysis would also consider the costs of alternatives, such as mechanical treatment of residuals, which can be used to achieve the same goal; however, in some instances, such as the preservation of natural ecosystems, there are few practical alternatives. Users of prescribed burning, if forced to reduce or stop the practice, would be expected to use some alternative procedures to at least partially compensate for the reduction in prescribed burning.

It has been suggested that emissions from prescribed burning are less than what would occur in its absense and are a minor source of pollution.

> In comparison with other sources, prescribed burning accounts for less than 2 percent of the particulate produced by all urban/industrial and rural/agricultural sources. Forest fires are more serious, producing possibly five times the particulates from prescribed burning. (Murphy, Fritschen, and Cramer, 1970, page 4.)

This implies that solely in terms of air quality, the benefits of prescribed burning--reduced damages from wildfires because they occur less often--outweigh the costs--periodic visual aesthetic damage and possibly health impacts caused by the smoke from prescribed burning.

The visibility benefit analysis techniques described in this guidebook are readily applicable for quantifying the visual aesthetic impacts and other costs and benefits of prescribed burning. The attributes of the prescribed burning or wildfire, such as frequency, duration and intensity, can be considered part of the necessary scenario development in much the same manner as for other sources of visual impacts. Because most such impacts would be located in nonurban areas, contingent market or travel cost and site substitution methods would probably be the most applicable benefit estimation techniques. The contingent market approaches, such as bidding methods, could be used to estimate damage to recreation, property, businesses, and wilderness resulting from prescribed burns and wildfires. Travel cost models could be used to estimate visitation rates and recreation benefits in affected areas before, during, and after periods of burns (prescribed and wildfire) and could then be used to calculate the benefits lost during and after the burn. Unfortunately, with the travel cost approach it would be difficult to separate air quality impacts from other impacts of such burning, such as loss of wildlife. This approach also will not capture the damages to local residents, to those passing through the area, or to those using impacted recreation areas without prior knowledge that the air quality conditions in the area would be affected by nearby burning.

GLOSSARY

Terms are defined in relation to their use in this guidebook.

Activity Value: A measure of value assigned to a good or service when it is in use. Also referred to as user value.

Bid Curve: A graphical representation of the quantities of a good that the consumer would be willing to purchase at each price of the good, with each price and quantity combination yielding the same utility.

Bid Function: A function relating stated WTP or WTA measures for visibility changes or levels to the visibility change or level, socioeconomic characteristics of the respondents and other explanatory variables.

Bidding Methods: A direct survey approach in which respondents are given information on a hypothetical situation and are asked through a structured procedure to estimate WTA and WTP measures.

Compensating Surplus (CS): A consumer surplus measure that is the change in income that, given a new quantity of a good, offsets the change in utility induced by the quantity change. The individual has the new quantity of the good but remains on the old indifference curve.

Compensating Variation (CV): A consumer surplus measure that is the change in income that, given a new price of a good, offsets the change in utility induced by the price change. The individual faces the new price but remains on the old indifference curve.

Consumer Surplus: The difference between what a consumer would be willing to pay rather than do without each unit of a good and what the consumer actually pays for each unit of the good.

Demand Curve: Same as Ordinary Demand Curve.

Discount Rate: An interest rate used to calculate the present value of future benefits or costs.

Equilibrium: In reference to the market for a good, it means that a price has been established at which the supply of the good equals the demand for the good. Equilibrium is the condition which when, or if, attained is stable as long as supply or demand conditions do not change.

Equivalent Surplus (ES): A consumer surplus measure that is the change in income that, given the old quantity of the good, yields the same change in utility as that induced by the quantity change. The individual has at the old quantity of the good but is on the new indifference curve.

Equivalent Variation (EV): A consumer surplus measure that is the change in income that, given the old price of a good, yields the same change in utility as the price change. The individual faces the old price but is on the new indifference curve.

Existence Value: The value assigned to the simple existence of a good, such as visibility aesthetics at a site.

Expenditure: The actual amount a consumer spends for a good or service.

Expenditure Function: Shows the change in expenditures that will maintain a designated level of an individual's utility when prices and/or environmental quality change.

Externality: Interaction between economic agents (i.e., firms or households) that brings costs or benefits to those agents without their consent in the absence of market determined compensation.

Hedonic Price: The implicit price of a non-market good or characteristic that is implied by the prices of associated market goods.

Hypothetical Bias: Inaccuracies or biases in survey responses occuring when a hypothetical situation is unfamiliar or unbelievable to respondents and results in misstatements of the responses.

Income Compensated Demand Curve (ICDC): The relationship between price of a good and quantity demanded when, for a given price change, the consumer's income is adjusted so that his utility remains constant.

Income Effect: That part of a change in the purchases of a good that can be attributed to the change in purchasing power that has resulted from a change in the price of the good.

Indifference Curve: A graphical representation of a set of consumption alternatives each yielding the same utility.

Information Bias: Variations in bidding method responses introduced by variation in the type of information provided in the survey instrument.

Market Segmentation: Occurs when the market for a good, such as housing, is made up of several distinct submarkets with unique supply and demand conditions in each.

Matched Pairs Technique: A procedure for selecting properties to be used in a hedonic price study by which neighborhood pairs are selected that are similar in all respects except the attribute to be priced.

Non-market Good: A good, such as a public good, that is not exchanged in a market and for which there is no directly observable price.

Normal Good: A good for which the quantity demanded at any price increases as income increases.

Offer Curve: A graphical representation of the quantities of a good that the supplier would be willing to supply at each price of the good, with each price and quantity combination yielding the same profit.

Option Value: A value assigned to the option to consume a good or service at a stated price at some future date.

Ordinary (Marshallian) Demand Curve (ODC): A curve showing the quantity of a good or service that a utility maximizing consumer or consumers with a given income level will demand at each price.

Payment Scheme: The method by which actual payments would be determined if a proposed plan were implemented. For example, all respondents pay the mean value, or all respondents pay their stated value, etc.

Payment Vehicle: The method by which payment for something is made, such as a user fee or a tax.

Price Elasticity: A measure of how responsive the quantity demanded or supplied is to a change in the price of a good. It is the percentage change in quantity divided by the percentage change in price.

Public Good: A good that is non-exclusive; that consumption by any one individual does not preclude consumption by other individuals. Since it can be provided to additional individuals without limiting its availability to others, the marginal cost of providing the good to additional individuals is zero.

Rejection Bias: Zero bids, infinity bids or bids which misrepresent true valuations because respondents reject some or all of the bidding method procedure.

Residential Location Model: A model that explains the household's residential location decision based on distance from central business district and neighborhood amenities.

Starting Point Bias: Inaccuracies in bidding method responses because the starting bid suggests information as to the expected final bid, thus influencing respondents to give bids other than their true value.

Strategic Bias: Inaccuracies in responses due to respondents systematically over or understating true values in an attempt to influence survey results.

Substitution Effect: That part of a change in the purchases of a good that can be attributed to substitution among goods that has resulted from a change in the price of the good relative to the prices of other goods.

Survey Instrument: Any type of survey form containing descriptions and the questions to be answered by respondents.

Utility: A qualitative measure of an individual's well being.

Utility Function: The relationship between an individual's utility and the quantity of goods and services consumed.

Vehicle Bias: In bidding methods, variations in responses due to variations in the payment vehicle used.

Weak Complementarity: Two goods are weakly complementary if when the quantity demanded of one is zero, the marginal utility for changes in the other good is zero.

Willingness to Pay (WTP): The maximum dollar amount an individual is willing to pay to promote an improvement or prevent a degradation in environmental quality.

Willingness to Accept (WTA): The minimum dollar amount an individual is willing to accept in compensation for a proposed degradation, or to forego a proposed improvement in environmental quality.

EPA AIR QUALITY REGULATION TERMS

Terms are defined in EPA (1980c).

Adverse impact on visibility means, for purposes of S307, visibility impairment which interferes with the management, protection, preservation, or enjoyment of the visitor's visual experience of the Federal Class I area. This determination must be made on a case-by-case basis taking into account the geographic extent, intensity, duration, frequency and time of visibility impairment, and how these factors correlate with (1) times of visitor use of the Federal Class I area, and (2) the frequency and timing of natural conditions that reduce visibility. This term does not include effects on integral vistas.

Best Available Retrofit Technology (BART) means an emission limitation based on the degree of reduction achievable through the application of the best system of continuous emission reduction for each pollutant which is emitted by an existing stationary facility.

Federal Land Manager means the Secretary of the department with authority over the Federal Class I area or, with respect to Roosevelt-Campobello International Park, the Chairman of the Roosevelt-Campobello International Park Commission.

Fugitive emissions means those emissions which could not reasonably pass through a stack, chimney, vent, or other functionally equivalent opening.

Integral vista means a view perceived from within the mandatory Class I Federal area of a specific landmark or panorama located outside the boundary of the mandatory Class I Federal area.

Mandatory Class I Federal Area includes all international parks, national wilderness areas, and the national memorial parks exceeding 5,000 acres and national parks exceeding 6,000 acres.

Natural conditions includes naturally occurring phenomena that reduce visibility as measured in terms of visual range, contrast, or coloration.

Reasonably attributable means attributable by visual observation or any other technique the state deems appropriate.

Significant impairment means, for purposes of S303, visibility impairment which, in the judgment of the Administrator, interferes with the management, protection, preservation, or enjoyment of the visitor's visual experience of the mandatory Class I Federal area. This determination must be made on a case-by-case basis taking into account the geographic extent, intensity, duration, frequency and time of the visibility impairment, and how these factors correlate with (1) times of visitor use of the mandatory Class I Federal area, and (2) the frequency and timing of natural conditions that reduce visibility.

Visibility impairment means any humanly perceptible change in visibility (visual range, contrast, coloration) from that which would have existed under natural conditions.

Visibility in any mandatory Class I Federal area includes any integral vista associated with that area.

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1. Consumer behavior theory, welfare economics and other economic theory.
2. Property value studies--theory and application.
3. Bidding method and studies related to contingent market approach--theory and application.
4. Travel cost site substitution studies, household production function, wages, voting and other techniques.
5. Economics of environment and natural resources.
6. Benefit-cost analysis and environmental control cost studies.
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8. Survey theory, statistical theory, mathematical modeling.
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Chipman, J.S., and Moore, J.C. 1980. "Compensating Variation, Consumer's Surplus, and Welfare." American Economic Review 70: 933-949. 1

Advanced theoretical presentation of conditions under which compensating variation measure can be used to rank alternative projects and how EV and CV can be derived from observable demand curves.

Cicchetti, Charles J., and Freeman, A. Myrick III. 1971. "Option Demand and Consumer Surplus: Further Comment." Quarterly Journal of Economics 85 (August): 528-539. 1

Shows that when there is a non-exclusive use of a good, depletable supply, and uncertainty in supply and demand, option values will be positive for risk averse individuals and should be computed and added to traditional user value consumer surplus benefits measures.

Cicchetti, Charles J., and Smith, V. Kerry. 1976. The Costs of Congestion. Cambridge, Massachusetts: Ballinger Publishing Company. 1, 5

Develops a theoretical model of the impacts of congestion on users of a common resource and presents an application of the model for estimating the impacts of congestion on an individual's wilderness recreational experience.

Clark, E. 1971. "Multipart Pricing of Public Goods." Public Choice 11 (Fall): 17-33. 1, 3

Clark, R.; Hendee, J.C.; and Cambell, F. 1971. "Values, Behavior and Conflict in Modern Camping Culture." Journal of Leisure Research. 3: 143-159. 7

Clawson, M. 1959. Methods of Measuring Demand for and Benefits of Outdoor Recreation. Reprint No. 10. Washington, D.C.: Resources for the Future, Inc. 5

Clawson, M., and Knetsch, J.L. 1966. Economics of Outdoor Recreation. Baltimore: Johns Hopkins Press. 5

Cornsweet, T.N. 1970. Visual Perception. New York and London: Academic Press. 7

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Craik, K.H. 1979. "The Place of Perceived Environmental Quality Indices (PEQIs) in Atmospheric Visibility Monitoring and Preservation." Proceedings of the Workshop in Visibility Values, Fort Collins, Colorado, January 28-February 1. General Technical Report WO-18. Washington, D.C.: U.S. Department of Agriculture. 7

Cramer, Owen P., and Pickford, Stewart G. 1973. "Factors Influencing Smoke Management Decision in Forest Areas." Proceedings of Air Quality and Smoke from Urban and Forest Fires International Symposium, October 24-26. 6

Crespi, I. 1971. "What Kinds of Attitude Measures are Predictive of Behavior?" Public Opinion Quarterly 35: 327-34. 3, 8

Cropper, M.L., and Arriaga-Salinas, A.S. 1980. "Intercity Wage Differentials and the Value of Air Quality." Journal of Urban Economics 8: 236-254. 4

Estimates labor supply and demand functions across several cities from which values of air quality are derived. Discussed in Section 4.4.4 of this guidebook.

Currie, J.M.; Murphy, J.A.; and Schmitz, A. 1971. "The Concept of Economic Surplus and Its Use in Economic Analysis." The Economic Journal 81: 741-799. 1

A complete review paper of all aspects of economic surplus accepted by the profession as of 1971.

Davis, R. 1963. "Recreation Planning as an Economic Problem." Natural Resources Journal 3: 239-249. 5

de Nevers, N. 1975. The Application of Cost-Benefit Analysis to Air Pollution Control Regulation: A General Discussion with Application to the Example of Sulfur Dioxide Control at the Huntington and Emery Powerplants. Salt Lake City: Utah Power and Light Company. 6, 7

_____. 1979. "Local Visibility and Power Generation in Central Utah." Paper presented at "View of Visibility--Regulatory and Scientific," Air Pollution Control Association Specialty Conference, Denver, Colorado, November 26-27. 7

Code

Devine, Hugh, and Smith, V. Kerry. 1981. "Visibility Benefit Analysis and Travel Cost Recreational Demand Models." (Mimeograph.) 4

Using the household production function approach to consumer behavior, demand models for recreation are developed and related to site attributes. This approach is tied to the travel cost models and the hedonic travel cost model.

Deyak, T.A., and Smith, V. Kerry. 1974. "Residential Property Values and Air Pollution: Some New Evidence." *Quarterly Review of Economics and Business* 14 (4): 93-100. 2

Estimates a property value function based on a residential location model across 100 U.S. cities using SMSA data; finds a significant negative relationship between property values and a measure of suspended particulates.

_____. 1978. "Congestion in Participation in Outdoor Recreation: A Household Production Function Approach." *Journal of Environmental Economics and Management* 5: 63-80. 4, 5

Diamond, P.A., and McFadden, D.L. 1974. "Some Uses of the Expenditure Function in Public Finance." *Journal of Public Economics* 3: 3-21. 1

Uses expenditure functions to examine the dead weight burden of taxation, optimal commodity taxes, and criteria for indivisible public investments financed by lump sum taxation.

Domencich, Thomas A., and McFadden, Daniel. 1975. *Urban Travel Demand: A Behavioral Analysis*. Amsterdam: North Holland Publishing Company. 1, 4

Drivas, P.J.; Bass, A.; and Heinold, D.W. 1980. "A Plume Blight Visibility Model for Regulatory Use." Symposium on Plumes and Visibility, Grand Canyon, Arizona, November 10-14. 7

Dwyer, J.F.; Kelly, J.R.; and Bowes, M.D. 1977. *Improved Procedures for Valuation of the Contribution of Recreation to National Economic Development*. WRC Research Report No. 128. Urbana, Illinois: Water Resources Center. 5

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Guidelines for the use of economic benefit measures and techniques applied to recreation experiences. Not specifically related to visibility.

Erskin, H. 1972. "The Polls: Pollution and its Costs." *Public Opinion Quarterly* 36: 120-135. 3

Ettenheim, George P.,Jr. 1979. *Considerations in Visibility Monitoring Measurements*. Altadena, California: Meteorology Research Inc., July. 7

Eubanks, Larry S., and Brookshire, David S. 1980. "Household Production and Non-Market Valuation." Paper presented American Economic Association meetings, Denver, Colorado, September. 4

Flagg, A.T. 1976. "Methodological Problems in Estimating Recreational Demand Functions and Evaluating Recreational Benefits." *Regional Studies 10*: 353-362. 5

Freeman, A. Myrick III. 1979a. *The Benefits of Environmental Improvement: Theory and Practice*. Baltimore and London: Johns Hopkins University Press for Resources for the Future, Inc. 1, 2, 4, 5

A thorough and sometimes technical discussion of the economic approach to understanding and identifying the benefits of environmental quality. The property value approaches are given a lengthy review.

_____. 1979b. "Hedonic Prices, Property Values and Meauring Envrionmental Benefits: A Survey of the Issues." *Scandinavian Journal of Economics* 81: 154-173. 2

An overview of the theoretical underpinnings of the hedonic price technique as it is applied to property value data to obtain willingness to pay for air quality similar to the presentation in Section 4.3.3 and in Freeman (1979a). The article includes responses to some of the criticisms of the approach that have been raised.

Freeman, A. Myrick III, and Haveman, Robert H. 1977. "Congestion, Quality Deterioration, and Heterogeneous Tastes." *Journal of Public Economics* 8: (October) 225-232. 1

Fromm, G. 1968. "Comment." *In Problems in Public Expenditure Analysis*. Edited by S.B. Chase, Jr. Washington, D.C.: Brookings Institute. 3

Code

Gibson, John G., and Anderson, Robert W. 1975. "The Estimation of Consumers' Surplus from a Recreational Facility with Optional Tariffs." Applied Economics 7: 73-79. 4

Goodwin, Susan Ann. 1977. "Measuring the Value of Housing Quality--A Note." Journal of Regional Science 17 (April): 107-115. 2

Presents the locational variables that were found to significantly influence monthly rents in the Boston area. These included an air pollution index and an employment accessibility index.

Griliches, Zvi, editor. 1971. Price Indexes and Quality Change. Cambridge, Massachusetts: Harvard University Press. 1, 2

Hammock, Judd, and Brown, Gardner, M. 1974. Waterfowl and Wetlands: Toward Bioeconomic Analysis. Baltimore: Johns Hopkins University Press for Resources for the Future, Inc. 3, 5

Hansen, Morris H.; Hurwitz, William N.; and Madow, William G. 1960. Sample Survey Methods and Theory, New York: John Wiley and Sons, Inc. 8

Sampling techniques and statistical distribution tests and variance calculations are presented.

Harrison, D., Jr., and Rubinfeld, D.L. 1978. "Hedonic Housing Prices and the Demand for Clean Air." Journal of Environmental Economics and Management 5 (March): 81-102. 2

A hedonic price study of property values in the Boston area, presented in Section 6.3.2.

Hause, John C. 1975. "The Theory of Welfare Cost Measurement." Journal of Political Economy 83: 1145-1182. 1

Heisler, S.L.; Henry, R.C.; Watson, J.G.; and Hidy, G.M. 1980. The 1978 Denver Winter Haze Study. Volume I: Executive Summary. Environmental Research and Technology Inc. Westlake Village, California, for Motor Vehicle Manufacturers Association. 7

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Hendee, J.C., and Burdge, R.J.; 1974. "The Substitutability Concept: Implications for Recreation Research and Management." Journal of Leisure Research. 6:155-162.	7
Hendee, J.C.; Gale, R.P.; and Cotton, W.R., Jr. 1971. "A Typology of Outdoor Recreation Activity Preferences." Journal of Environmental Education. 3:28-34.	7
Henderson, A. 1941. "Consumer Surplus and the Compensating Variation." The Review of Economic Studies 8: 117-121.	1
Henry, R.C. 1979a. "Psychophysics and Visibility Values in Proceedings of the Workshop in Visibility Values." Edited by Fox et al., Fort Collins, Colorado, January 28-February 1. USDA General Technical Report WO-18.	7
_____. 1979b. "The Human Observer and Visibility-Modern Psychophysics Applied to Visibility Degradation." Paper presented at "View on Visibility-Regulatory and Scientific," Air Pollution Control Association Specialty Conference, Denver, Colorado., November 26-27.	7
Hicks, J.R. 1941. "The Rehabilitation of Consumers' Surplus." The Review of Economic Studies 8: 108-116.	1
_____. 1944. "The Four Consumers' Surplus." Review of Economic Studies 11 (Winter): 31-41.	1
_____. 1945-46. "The Generalized Theory of Consumer's Surplus." Review of Economic Studies 13: 68-74.	1
_____. 1956. A Revision of Demand Theory. Oxford: Clarendon Press.	1
Hirshleifer, Jack. 1976. Price Theory and Applications. Englewood Cliffs, New Jersey: Prentice-Hall, Inc. A textbook of intermediate level economic theory and practice.	1
Hori, H. 1975. "Revealed Preferences for Public Goods." American Economic Review 65: 978-991.	1

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Husar, R., and White, W. 1976. "On the Color of the Los Angeles Smog." *Atmospheric Environment* 10: 199-204.	7
Husar, R.B. et al. 1979. "Trends of Eastern U.S. Haziness Since 1948." Paper presented at the Fourth Symposium of Atmospheric Turbulence, Diffusion and Air Pollution, Reno, Nevada, January 15-18.	7
Hylland, Aanund, and Zeckhauser, Richard. 1979. "The Efficient Allocation of Individuals to Positions." *Journal of Political Economy* 87: 293-314.	1, 4
_____. 1979. "The Impossibility of Bayesian Group Decision Making With Separate Aggregation of Beliefs and Values." *Econometrica* 47: 1321-1336.	1, 4
ICF Incorporated. 1980. "Preliminary Assessment of Economic Impact Visibility Regulations: Draft Report." Washington, D.C.	6
Intriligator, Michael D. 1978. *Econometric Models, Techniques and Applications*. Englewood Cliffs, New Jersey: Prentice-Hall Inc.	8
James, T.H., editor. 1977. *The Theory of the Photographic Process*. 4th Edition. New York: Macmillan & Company.	7
Kain, John F., and Quigley, John H. 1972. "Housing Market *Discrimination, Homeownership, and Savings Behavior."* *American Economic Review* 62: 263-277.	2
Kneese, Allen W., and Bower, Blair T. 1972. *Environmental Quality Analysis: Theory and Method in Social Sciences*. Baltimore and London: Johns Hopkins University Press for Resources for the Future, Inc.	5
Kneese, A. and Williams, M. 1978. "Environmental Aspects of Resources Policy for a Regional Setting." Department of Economics, University of New Mexico, Albuquerque. (Mimeograph.)	5
Knetsch, J. L. 1963. "Outdoor Recreation Demand and Benefits." *Land Economics* 39: 387-396.	4

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_____. 1974. *Outdoor Recreation and Water Resource Planning*. 4
Water Resources Monograph No. 3. Washington, D.C.: American Geophysical Union.

Knetsch, J.L., and Cesario, F.J. 1976. "Some Problems in 4
Estimating the Demand for Outdoor Recreation: Comment." *American Journal of Agricultural Economics* 58 (August): 596-597.

Krutilla, John V.; Cicchetti, Charles J.; Freeman, A. Myrick III; 5
and Russell, Clifford S. 1972. "Observations on the Economics of Irreplaceable Assets." In *Environmental Quality Analysis: Theory and Method in Social Science*. Edited by Allen Kneese and Blair T. Bower. Baltimore and London: Johns Hopkins University Press for Resources for the Future, Inc.

A case study of Hells Canyon showing preservation values exceeding opportunity costs and that inclusion of option values may have increased preservation benefits.

Krutilla, John V., and Fisher, Anthony C. 1975. *The Economics 5
of Natural Environments: Studies in the Valuation of Commodity and Amenity Resources*. Baltimore and London: Johns Hopkins University Press for Resources for Future, Inc.

Kurz, Mordecai. 1974. "An Experimental Approach to the Deter- 4
mination of the Demand for Public Goods." *Journal of Public Economics* 3: 329-348.

Lancaster, Kelvin J. 1966. "A New Approach to Consumer Theory." 1
Journal of Political Economy 74 (April): 132-157.

Lansing, John B., and Morgan, James N. 1974. *Economic Survey 8
Methods*. Ann Arbor: University of Michigan Press.

Comprehensive analysis of survey procedures and analysis for economics.

Latimer, Douglas A., and Daniel, Terry C. 1979. "Preliminary 7
Results of a Study of Human Judgements of Visial Air Quality." Paper presented at the Air Pollution Control Association Conference on Visibility, Denver, Colorado, November.

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Latimer, D.; Daniel, D.A.; Hogo, H. 1980. "The Effect of Atmospheric Optical Conditions on Perceived Scenic Beauty." Symposium on Plumes and Visibility, Grand Canyon, Arizona, November 10-14.	7
Layard, P.R.G., and Walters, A.A. 1978. *Microeconomic Theory*. New York: McGraw-Hill Book Company.	1
Lea, S.E.G. 1978. "The Psychology and Economics of Demand." *Psychological Bulletin* 85: 441-466.	3
Lind, R.C.; Arrow, K.J.; Corey, G.; Dasgupta, P.; Sen, A.; Stauffer, T.; Stiglitz, J.E.; Stockfish, J.; and Wilson, R. 1982. *Discounting for Time and Risk in Energy Policy*. Baltimore and London: Johns Hopkins University Press for Resources for the Future, Inc.	6
Locander, William; Sudman, Seymore; and Bradbury, Norman. 1976. "An Investigation of Interview Threat and Response Distortion." *Journal of the American Statistical Association* 71: 268-275.	8
Loehman, Edna; Boldt, David; and Chaikin, Kathleen. 1980. "Measuring the Benefits of Air Quality Improvements in the San Francisco Bay Area. Part I: Study Design and Property Value Study." Draft final report. Menlo Park, California: SRI International, September. A hedonic property value study of the San Francisco area as part of a replication of the South Coast Air Basin study, discussed in Section 6.3.5 of this guidebook.	2
Lucas, R.C. 1964. "Wilderness Perceptions and Use: The Example of the Boundary Waters Canoe Area. *Natural Resources Journal*. 3:394-411	7
Lucas, R.C., and Stankey G.H. 1973. "Social Carrying Capacity for Backcountry Recreation." In *Outdoor Recreation Research: Applying the Results*. Forest Service General Technical Report NC-9, St. Paul Minnesota.	7
Maler, K. 1974. *Environmental Economics: A Theoretical Inquiry*. Baltimore and London: Johns Hopkins University Press. Advanced theoretical treatise on economics of the environment.	1, 5

Code

Maler, K., and Wyzga, Ronald E.. 1976. *Economic Measurement of Environmental Damage: A Technical Handbook*. Paris: Organization for Economic Cooperation and Development. 1, 5, 6

Discusses general valuation techniques and economic benefit measures for a broad class of environmental damages.

Malm, William; Leiker, Karen; and Molenar, John. 1979. "Human Perception of Visual Air Quality." Paper presented at the Air Pollution Control Association meeting, Denver, Colorado, November. 7

Malm, W.C.; Kelley, K.; and Molenar, J. 1980a. "Human Perception of Visual Air Quality (Regional Haze)." Symposium on Plumes and Visibility, Grand Canyon, AZ, November 10-14. 7

_____. 1980b. "Human Perception of Visual Air Quality (Layered Haze)." Symposium on Plumes and Visibility, Grand Canyon, Arizona, November 10-14. 7

Marshall, Alfred. 1920. *Principles of Economics*. 8th edition. London: Macmillan & Company. 1

McFadden, Daniel. 1977. "Quantitative Methods for Analyzing Travel Behavior of Individuals: Some Recent Developments." Institute of Transportation Studies Working Paper No. 7704. University of California, Berkeley. 4

Mendelsohn, Robert. 1980. "An Economic Analysis of Air Pollution from Coal-Fired Power Plants." *Journal of Environmental Economics and Management* 7 (March): 30-43. 6

Performs a benefit-cost analysis for coal-fired power plants in the New Haven, Connecticut area. Optimum rates of emission control are estimated drawing upon a Gaussian dispersion model; dose response rates; estimated benefits for acid rain, materials, agricultural and visibility aesthetics; and estimated costs for control technologies.

Middleton, W.E.K. 1952. *Vision Through The Atmosphere*. Toronto: University of Toronto Press. 7

Mikesell, Raymond, F. 1977. *The Rate of Discount for Evaluating Public Projects*, Washington, D.C.: American Enterprise Institute for Public Policy Research. 5, 6

Code

A useful treatise which addresses the basic issue concerning the social rate of discount and the application to several types of public projects. Issues addressed include the opportunity cost of capital, taxation, future generations, exhaustible natural resources and inflation.

Miller, Jon, R. and Lad, Frank. 1981. "Uncertainty, Irreversibility, and Quasi-Option Value: A Bayesian Approach." Paper presented at the 1981 Western Economic Association Meetings, San Francisco, California. 1

Contrary to Arrow and Fisher (1974), the paper, using a complete Bayesian framework, demonstrates that with a proper treatment of uncertainty in the face of irreversibility, development decisions with quasi-option demand are not necessarily more conservative than decisions without the quasi-option. The paper also introduces reneg opportunities and reneg values.

Mishan, E.J. 1972. Economics for Social Decisions: Elements of Cost-Benefit Analysis. New York and Washington: Praeger Publishers. 6

Non-mathematical discussion of the basic rational and concepts of cost-benefit analysis, useful to readers with basic knowledge of economics.

_____. 1976. Cost-Benefit Analysis: An Introduction. New York and Washington: Praeger Publishers. 6

Mood, A.M.; Graybill, F.A.; and Boes, D.C. 1974. Introduction to the Theory of Statistics. 3rd edition. New York: McGraw-Hill Book Company. 8

Muellbauer, John. 1974. "Household Production Theory, Quality, and the 'Hedonic Technique.'" The American Economic Review 64 (December): 977-994. 4

A theoretical discussion that criticizes the use of household production approach to develop price indexes that account for quality changes and concludes that household production theory will be useful in this respect only if the househhold production function is nonjoint and has constant returns to scale, which will not typically be the case.

Code

Mumpower, J.; Middleton, P.; Dennis, R.L.; Stewart, T.R.; Veirs, V. 1980. "Visual Air Quality Assessment: Denver Case Study." Symposium on Plume Visibility, Grand Canyon, Arizona, November 10-14. 7

Murphy, James L.; Fritschen, Leo J.; and Cramer, Owen P. 1970. "Slash Burning: Pollution Can Be Reduced." Fire Control Notes 31 (3): 3-5. 6

Muth, Richard S. 1966. "Household Production and Consumer Demand Func]ions." Econometrica 34 (July): 699-708. 4

Nelson, Jon P. 1978. "Residential Choice, Hedonic Prices, and the Demand for Air Quality." Journal of Urban Economics 5: 357-369. 2

Presents the Washington D.C. Study that is discussed in Section 6.3.1.

Niskanen, William A., and Hanke, Steve H. 1977. "Notes: Land Prices Substantially Underestimate the Value of Environmental Quality." The Review of Economics and Statistics 59 (August): 375-377. 2

Points out that most property value studies to derive the benefits of air pollution control have overlooked the effects of a change in air quality on property tax revenues and have therefore underestimated the benefits of a reduction in air pollution.

Palmquist, Raymond B. 1981. "Measuring Environmental Effects on Property Values Without Hedonic Regressions." Journal of Urban Economics. (Forthcoming.) 2

Describes the repeat-sale technique that uses differences in sale prices of the same homes before and after a change in environmental quality to estimate the value of the change. Applies it to a change in noise levels after the construction of an interstate highway through a neighborhood in Seattle.

Patinkin, Don. 1963. "Demand Curves and Consumer's Surplus." In Measurement in Economics: Studies in Mathematical Economics and Econometrics in Memory of Yehuda Grunfeld. Edited by Carl Christ et al. Stanford, California: Stanford University Press. 1

Code

Paulson, N.R. 1979. "Some Perspectives on Visibility and Land Management." Proceedings of the Workshop in Visibility Values, Fort Collins, CO, January 28-February 1, U.S. Dept. of Agriculture General Technical Report WO-18. 5, 9

Pearse, P.H. 1968. "A New Approach to the Evaluation of Non-Priced Recreational Resources." Land Economics 44 (February): 89-92. 4

Applies a variation of the travel cost method to estimate consumer surplus valuations.

Pendse, Dilip, and Wyckoff, J.B. 1974. "Reports and Comments: Scope for Valuation of Environmental Goods." Land Economics 50 (February): 89-92. 3

Pindyck, Robert S., and Rubinfeld, Daniel L. 1976. Econometric Models and Economic Forecasts. New York: McGraw-Hill Book Company. 8

Intermediate level theory and application of econometrics text.

Polinsky, Mitchell A. 1972. "Probabilistic Compensation Criteria." Quarterly Journal of Economics 86 (August): 407-425. 1

Polinsky, Mitchell A., and Shavell, Steven. 1975. "The Air Pollution and Property Value Debate." The Review of Economics and Statistics 57 (February): 100-104. 2

A criticism of the theoretical justification offered by Anderson and Crocker (1972) for their property value study of St Louis (Anderson, Crocker, 1971) and an initial description of the residential location model introduced in Section 4.3.4.

_____. 1976. "Amenities and Property Values in a Model of an Urban Area." Journal of Public Economics 5: 119-129. 1, 2

Presents the theoretical residential location model that was introduced in Section 4.3.4 in an effort to explain the relationship between amenities and property value with emphasis on the effect of different levels of household mobility.

	Code
Polinsky, Mitchell A., and Rubinfeld, Daniel L. 1977. "Property Values and the Benefits of Environmental Improvements: Theory and Measurement." In *Public Economics and the Quality of Life*. Edited by Lowdon, Wingo, and Evans. Baltimore and London: Johns Hopkins University Press for Resources for the Future, Inc. Presents a theoretical discussion of the residential location model that was introduced in Section 4.3.4 and describes its application in the St. Louis metropolitan area.	1, 2
Pollak, R., and Wachter, M. 1975. "The Relevance of the Household Production Functions and Its Implications for the Allocation of Time." *Journal of Political Economy* 83: 255-277. Presents a theoretical argument that applications of the household production approach that make use of implicit prices of characteristics require that the household production function have constant returns to scale and be nonjoint; similar to the conclusions of Muelbauer (1974).	1, 4
Portney, Paul R. 1975. "Voting, Cost-Benefit Analysis, and Water Pollution Policy." In *Cost-Benefit Analysis and Water Pollution Policy*. Edited by Henry M. Peskin and Eugene Seskin. Washington, DC: The Urban Institute.	4, 6
Rae, Douglas A. 1980. "Visibility Impairment at Mesa Verde National Park: An Analysis of Benefits and Costs of Controlling Emissions in The Four Corners Area." A Charles Rivers Associates, Inc. Interim Report for the Electric Power Research Institute, December. Applies the ranked attribute approach to visibility benefit analysis at Mesa Verde. See Section 4.4.1.	4
Randall, A.; Ives, B.; and Eastman, C. 1974a. "Bidding Games for Valuation of Aesthetic Environmental Improvements." *Journal of Environmental Economics and Mangement* 1: 132-149. The original bidding method application to visual aesthetics, better known as the Four Corners study. See Section 6.2.1 of this guidebook.	3
_____. 1974b. "Benefits of Abating Aesthetic Environmental Damage from the Four Corners Power Plant, Fruitland, New Mexico." Bulletin 618. New Mexico State University Agricultural Experiment Station.	3

Code

Randall, A.; Grunewald, O.; Johnson, S.; Ausness, R.; and Pagoulatos, A. 1978. Estimating Environmental Damages from Surface Mining of Coal in Appalachia: A Case Study. EPA-600/2-78-003. Washington, D.C.: USEPA, January. 3, 6

Comprehensive and integrated examination of the benefits of surface mine reclamation. Bidding methods are used to estimate aesthetics-related benefits.

_____. 1978. "Reclaiming Coal Surface Mines in Central Appalachia: A Case Study of the Benefits and Costs." Land Economics 54: 472-489. 3, 6

A summary of the report on the same topic, listed above.

Randall, A., and Stoll, J. 1980. "Consumers' Surplus in Commodity Space." American Economic Review 70 (July): 449-455. 1

Discusses and calculates the error in measurement incurred by using the ordinary consumer surplus measure when ES or CS measures are appropriate. See Chapter 2 of this guidebook.

Ridker, Ronald G., and Henning, John A. 1967. "The Determinants of Residential Property Values With Special Reference to Air Pollution." The Review of Economics and Statistics 49 (May): 246-257. 2

First attempt to use property value data to estimate the benefits of air pollution control based on the observed differences in property values with respect to air quality. They found a statistically significant relationship between a measure of sulfur oxides and property values in St. Louis, although their interpretation of property value differentials as directly reflecting benefits of pollution control was later criticized.

Roberts, E.M.; Gordon, J.L.; Hoase, D.L.; Kary, R.E.; and Weiss, J.R. 1974. "Visibility Measurements in the Painted Desert through Photographic Photometry." Bulletin No. 47. Denver, Colorado: Dames and Moore Engineering. 7

Robinson, E. 1970. "Effect on the Physical Properties of the Atmosphere." In Vol. 1: Air Pollution. Edited by A. Stern. Academic Press. 7

Code

Rosen, Sherwin. 1974. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." *Journal of Political Economy* 82 (January/February): 34-55. — 1, 2

A technical discussion of the equilibrium conditions in a market for a differentiated product. The theory of hedonic prices and potential applications to estimating demand for a characteristic of a product are consistant with Freeman (1974) and have been the basis of many property value studies that have estimated willingness to pay for air quality, as described in Section 4.3.3 of this guidebook.

_____. 1979. "Wage-based Indexes of Urban Quality in Life." In *Current Issues in Urban Economics*. Edited by Peter Mieszkowski and Mahlon Straszheim. Baltimore and London: Johns Hopkins University Press. — 1, 4

Estimates a hedonic price function for wages across several cities from which values of air quality are derived. Discussed in Section 4.4.4 of this guidebook.

Rowe, R.; d'Arge, R.; and Brookshire, D. 1980a. "An Experiment on the Economic Value of Visibility." *Journal of Environmental Economics and Management* 7 (March): 1-19. — 3

Summary article on the Farmington study focusing upon biases in the bidding method. See Section 6.2.3 of this guidebook.

_____. 1980b. "Environmental Preference and Effluent Charges." In *Progress in Resource Management and Environmental Planning*. Edited by Timothy O'Riordin and R. Kerry Turner. London: John Wiley & Sons, Ltd. Series in Environmental Economics. — 3

Summary of the Farmington study; focuses upon aggregate benefits and policy applications for emissions control. See section 6.2.3 of this guidebook.

Rowe, Robert D. and Blank, Frederick M. 1981. "Deviations In Empirical Consumers' Surplus Measures." Paper presented at the Fifty-Sixth Conference of the Western Economics Association, San Francisco, California. — 3

Addresses a broad spectrum of arguments as to why empirical ES and CS measures have substantially deviated and the implications for measure selection and application of benefit estimation techniques.

Code

Samuelson, P.A. 1954. "The Pure Theory of Public Expenditures." Review of Economics and Statistics 36 (November): 387-389. 1

Sandler, Todd, and Smith, V. Kerry. 1976. "Intertemporal and Intergenerational Pareto Efficiency." Journal of Environmental Economics and Management 2 (February): 151-159. 1

Efficiency conditions are derived for both public and private goods which provide benefits over time.

_____. 1977. "Intertemporal and Intergenerational Pareto Efficiency Revisited." Journal of Environmental Economics and Management 4: 252-257. 5, 6

Sassone, Peter G., and Schaffer, William A. 1978. Cost-Benefit Analysis: A Handbook. London: Academic Press. 6

A thorough, step-by-step handbook discussing the philosophy and application of benefit cost analysis.

Scherr, Bruce A., and Babb, Emerson, M. 1975. "Pricing Public Goods: An Experiment with Two Proposed Pricing Systems." Public Choice 23: 35-48. 3

Analyzes bidding behavior for a concert and library fund under three alternative payment schemes. They could not reject that any scheme inhibited "free rider" behavior. Also, mean bids under the three schemes were significantly different.

Schmalensee, R. 1972. "Option Demand and Consumer's Surplus: Valuing Price Changes under Uncertainty." The American Economic Review 62: 813-824. 1

Theoretical paper which shows that consideration of alternative project site uses and the consideration of risk preferences may lead to both positive or negative option values for a specified project.

Schulze, W., and d'Arge, R. 1977. "On the Valuation of Recreation Damages." Paper presented at the American Economic Association, December. 4

Code

Silberberg, Eugene. 1972. "Duality and the Many Consumer's Surpluses." American Economic Review 5: 942-952. 1

Sinden, J.A. 1974. "A Utility Approach to the Valuation of Recreational and Aesthetic Experiences." American Journal of Agricultural Economics 56 (February): 61-72. 1, 4

Sinden, J.A. 1979. Unpriced Values. New York: John Wiley and Sons. 5

Small, Kenneth A., and Rosen, Harvey S. 1981. "Applied Welfare Economics with Discrete Choice Models." Econometrica 49 (January): 105-130. 1

Analyzes methods of applied welfare economics in cases of discrete choice using advanced theory.

Smith, Barton A. 1978. "Measuring the Value of Urban Amenities." Journal of Urban Economics 5: 370-387. 2

Derives a measure of land value premiums from differences between land prices at different locations and using data from Chicago; finds a significant negative relationship between this location premium and air pollution in a hedonic price function.

Smith, V. Kerry. 1975. "The Estimation and Use of Models of the Demand for Outdoor Recreation." In Assessing Demand for Outdoor Recreation. Washington, D.C.: U.S. Department of Interior, Bureau of Outdoor Recreation. 1, 4

_____. 1976. The Economic Consequences of Air Pollution. Cambridge, Massachusetts: Ballinger Publishing Company. 2

Pulls together several articles on economic approaches to quantifying the damages of air pollution with emphasis on property value studies; includes the results of a cross-city property value study that was based on the residential location model.

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Code

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Stankey, G.H. 1972. "A Strategy for the Definition and Management of Wilderness Quality." In Natural Environments: Studies in Theoretical and Applied Analysis. Edited by J.V. Krutilla. Baltimore: Johns Hopkins Press.	5, 7
___________. 1973. "Visitor Perception of Wilderness Recreation Carrying Capacity." Forest Service Paper INT-142. Ogden Utah.	7
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Code

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Trijonis, J. 1979. "Visibility in the Southwest: An Exploration of the Historical Data Base." Atmospheric Environment 13: 833. 7

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U.S. Department of Agriculture. 1977. Forest Service. Outdoor Recreation: Advances in the Application of Economics. Proceedings of a National Symposium, March. 4

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U.S. Environmental Protection Agency. 1975. Guidelines of Reclassification of Areas under EPA Regulations to Prevent the Significant Deterioration of Air Quality. June. 9

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_____. 1979. Protecting Visibility: An EPA Report to Congress. EPA-450/5-79-008. 7, 9

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Code

_____. 1980b. Proposed Guidelines for Determining Best Available Retrofit Technology for Coal-Fired Power Plants and Other Existing Stationary Facilities. EPA-450/3-80-009, March. 9

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Final rulemaking for Phase I protection of clean air in Class I areas authorized under the Clean Air Act as amended 1977.

_____. 1980d. Workbook for Estimating Visibility Impairment. EPA-450/4-80-031. 7

_____. 1980e. User's Manual for the Plume Visibility Model (PLUVUE). EPA-450/4-80-032. 7

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Code

Wilman, Elizabeth A. 1981. "Hedonic Prices and Beach Recreational Values." In Advances in Applied Microeconomic Theory. Edited by V.K. Smith. Greenwich, Connecticut: JAI Press. (Forthcoming.) 2

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APPENDIX 1

Sample Bidding Method Questionnaires and Picture Sets

Page

A. The Lake Powell Study A-1

B. The Farmington Study A-3

C. The South Coast Air Basin Study A-14

D. The Grand Caynon/Southwest Parks Study A-37

E. Water Resource Council Suggested Contingent Market Valuation Techniques to Estimate Recreation Benefits A-41

A. THE LAKE POWELL STUDY

Reproduced from best available copy.

BROOKSHIRE, IVES AND SCHULZE

QUESTIONNAIRE

Bidding Game for Estimation of Recreationists' Demand
for Abatement of Aesthetic Environmental Damage

Good Morning/Afternoon. My name is ________________. I'm doing research for the Economics Department at the University of New Mexico, as a part of the Lake Powell Research Project, funded by the John Muir Institute for Environmental Studies.

This research is designed to more closely examine some of the trade-offs between industrial development, recreation, and the environment in the Lake Powell area. In connection with these objectives, I would like to ask you a few questions to see how you feel about environmental quality and its future in this area.

1. How many members of your family are here with you? ________ persons.

2. What is the expected length of your stay? ________ days.

3. Where are you staying?
________ (a) local resident
________ (b) lodge, Page motel
________ (c) passerby
________ (d) developed or semi-developed campground
________ (e) remote (specify location)
____

4. If you don't mind, could you please indicate which of the following brackets your family income falls into:

________________	0 - 4,999	________________	20,000 - 24,999
________________	5,000 - 9,999	________________	25,000 - 29,999
________________	10,000 - 14,999	________________	30,000 - 49,999
________________	15,000 - 19,999	________________	50,000 and up

There are plans to construct a large electric generating plant north of Lake Powell. This plant is expected to be at least as large as the Navajo Plant on the south side of the lake.

5. Have you noticed the Navajo Plant or its smokestacks? ________ yes ________ no

Depending on exactly where and how a new plant is constructed, it could have a significant effect on the quality of the environment. If the plant is built near the lake, it could be visible for many miles up and down the lake. If air pollution is not strictly controlled, visibility in the area may be significantly affected.

These photographs (show) are designed to show how a new powerplant on the north side of the lake might appear. Situation A shows a possible plant site but assumes that the powerplant would be built at some distant location, not visible from the lake area. In Situation B the powerplant is easily seen from the lake, but emits very little smoke; visibility is virtually unaffected. Situation C is intended to show the situation with the greatest impact on the environment of recreationists in the area. It is easily seen from the lake, and the smoke substantially reduces visibility.

Vacationers, of course, spend considerable amounts of money and time and effort to equip themselves with vehicles, boats, camping and fishing gear, and for traveling to the destination of their choice. It is reasonable to assume that the amount of money you are willing to spend for a recreational experience depends, among other things, on the quality of the experience you expect. An improved experience would be expected to be of greater value to you than a degraded one. Since it does cost money to improve the environment, we would like to get an estimate of how much a better environment is worth to you.

First, let's assume that visitors to GCNRA are to finance environmental improvements by paying an entrance fee to be admitted into the recreation area. This will be the only way to finance such improvements in the area. Let's also assume that all visitors to the area will pay the same daily fee as you, and all the money collected will be used to finance the environmental improvements shown in the photos.

6. Would you be willing to pay a $1.00 per day family fee to prevent Situation C from occurring, thus preserving Situation A? $2.00 per day? (increment by $1.00 per day until a negative response is obtained, then decrease the bid by 25¢ per day until a positive response is obtained, and record the amount.)

________ $/day

7. Would you be willing to pay a $1.00 per day fee to prevent Situation B from occurring, thus preserving Situation A? (repeat bidding procedure).

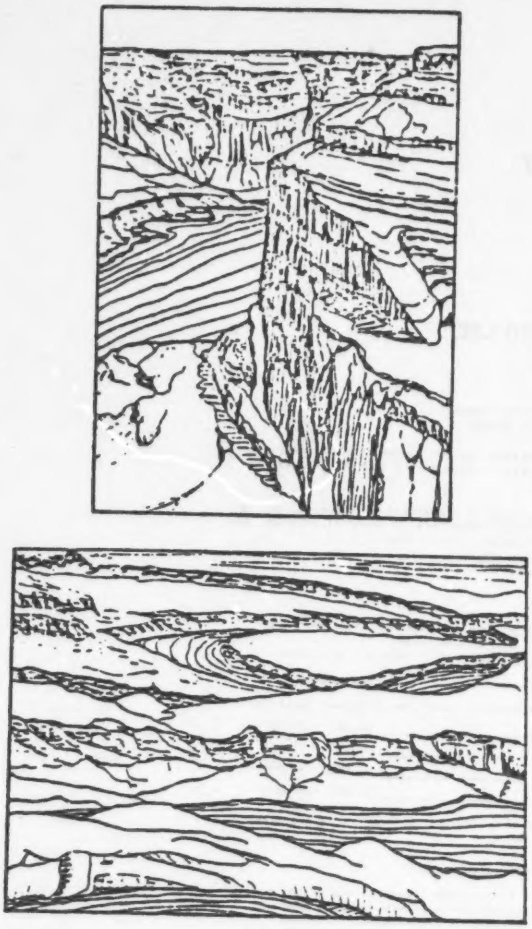
________ $/day

8. (Answer only if a zero bid was recorded for question 6 or 7 above.) Did you bid zero because you believe that:

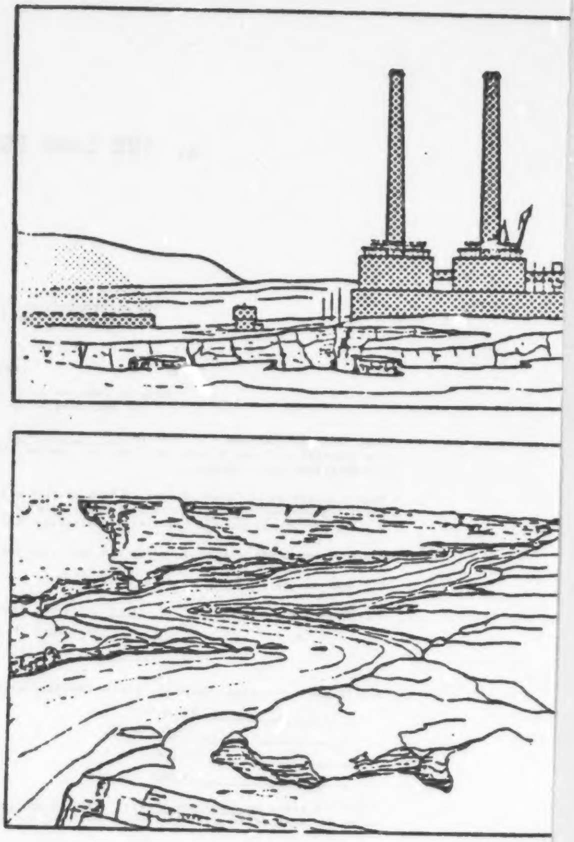
________ the damage is not significant
________ it is unfair or immoral to expect the victim of the damage to have to pay the costs of preventing the damage
________ Other (specify) ________________________________

9. In your opinion, has visibility, depth or color perception in this area been significantly reduced by air pollution:

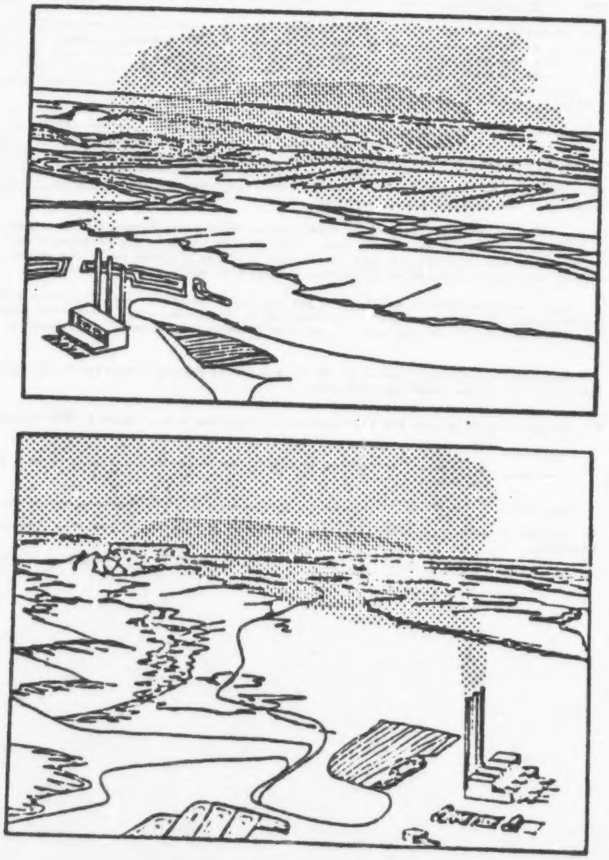
________ significantly so ________ only very minor ________ insignificantly or not at all



Situation A.



Situation B.



Situation C.

B. THE FARMINGTON STUDY

QUESTIONNAIRE - BIDDING GAME
Estimation of Aesthetic Damages of Air Pollution from Coal Fired Power Plants

Good morning/afternoon. My name is _____ (PRESENT ID). I am from the Department of Economics at the University of Wyoming. We are doing research under a grant from the Electric Power Research Institute which is funded by the power plants across the nation. What we are attempting to do is measure the value of better visibility associated with increased emission control from coal-fired electric generating plants. In order for us to do this would you be willing to answer some questions about visibility in this area?

PART I

1. JOINT QUESTIONNAIRE _______ SINGLE QUESTIONNAIRE _______.

2. Have you recently completed any other questionnaire for the University of Wyoming? ____yes ____no. (IF YES AND NOT A JOINT QUESTIONNAIRE THANK THEM FOR THEIR TIME AND EXCUSE YOURSELF.)

3. Sex: ____male ____female.

4. Marital Status: ____single ____married ____other (SPECIFY).

5. Number of persons in your household/group: _______.

6. Occupation: ___________________Name of Employer: ___________________.

7i. Are you a resident of the Four Corners area? ____resident ____nonresident.

ii. (FOR NONRESIDENTS)

   A. Where are you staying? ____a) lodge or motel ____b) local residence ____c) developed or semi-developed campground ____d) other.

   B. What state _____________ and county ____________ are you from?

   C. Are you on vacation ______ or business ________?

8. How long have you been in the Four Corners area? ____________________.

9. Do you have regular access to an automotive vehicle? ____yes ____no.

10. If children are living with you what is the age of your youngest child? ____yes children ____no children _______ age of youngest child.

Thank you.

As you may know, there are presently two power plants in the Four Corners area. These plants use coal to generate electric power. The need for maintaining and perhaps increasing the nation's energy resources is represented by these plants. Coupled with further energy development, however, is the problem of stack emissions from power plants. In order to study the possibility of overspending or underspending on emissions control by power companies the Electric Power Research Institute has commissioned this effort. The purpose is to determine how individuals are affected by visibility changes induced by power plant emissions.

(PRESENT THE PHOTOGRAPHS) These photographs are designed to show varying degrees of visibility. Column A depicts a situation with high visibility, while B and C show decreasing levels of visibility due to increased emissions and dust in the air. Column D depicts the visible stacks and emissions of the plants. While the pictures may include some windblown dust, they represent typical levels of visibility that could occur if the power plants reduced their emission control. Each column represents the same visibility for two different views: Shiprock to the west and the San Juan Mountains to the north.

PART II. EQUIVALENT VARIATION

Clearly, everyone desires cleaner air, however, air quality improvements entail considerable expenditures. Let us propose a mechanism to continue to finance improvements in visibility.

(FOR RESIDENTS) Suppose the method used to finance emission control will be through (_____) additional monthly charges on your utility bill (_____) additional payroll deductions (CHECK WHICH) and everyone would have to pay the same amount.

(FOR NONRESIDENTS) Suppose the method used to finance emission control will be through additional fees to parks, campgrounds and a surtax on gas, food and lodging. (ALSO SUBSTITUTE DAYS FOR MONTHS.)

(DO EITHER 1,2,3,4____ or 3a,1,2,4____SEQUENTIALLY. CHECK THE ONE USED.)

1a) With this in mind, would you be willing to pay $____ (USE STARTING BID OF $1,5, or 10) per month (extra on your utility bill) (as a payroll deduction) to have visibility as depicted in Column A rather than as depicted in Column B? (GO THROUGH BIDDING PROCESS.)

b) (REPEAT CHANGING COLUMN B TO COLUMN C.)

c) (REPEAT COMPARING B AND C.)

d) Similarly the power plants and their emissions may be out in the open, such as a combination of Columns C and D depicts, or hidden from view, for

ORIGINAL BIDS

1a. $____________
b. $____________
c. $____________
d. $____________

instance behind a mesa, and the emissions level could be as in Column A. (REPEAT BIDDING GAME COMPARING THE COMBINATION OF C AND D WITH A.)

2. Did you bid zero because you believe that: (HAND RESPONDENT THE AUXILLIARY SHEET WITH ALTERNATIVES. MORE THAN ONE ANSWER IS ACCEPTABLE BUT NOT ENCOURAGED. RECORD ANSWER HERE:) ________________.

3a. Suppose you were told that the average amount people were willing to pay in other studies of similar circumstances was:

$1.25 to have typical visibility as depicted in Column A rather than as depicted in Column B

$1.50 to have typical visibility as depicted in Column A rather than as depicted in Column C

$ .25 to have typical visibiltty as depicted in Column B rather than as depicted in Column C.

$1.75 (IF 3a IS DONE FIRST READ 1c) to have visibility as depicted in Column A rather than as depicted in the combination of Columns C and D.

3b.. i) Given this information, what would you be willing to pay to have visibility as in A rather than as in B?

ii) Given this information, what would you be willing to pay to have visibility as in A rather than as in C?

iii) Given this information, what would you be willing to pay to have visibility as in B rather than as in C?

iv) Given this information, what would you be willing to pay to have visibility as in A rather than as in C + D?

REVISED BIDS

3b. i. $________________
ii. $________________
iii. $________________
iv. $________________

3c. Why did/didn't you change your bids?

____

QUESTIONNAIRE - BIDDING GAME

4. If your bid to change the visibility from that depicted in C to that shown in A actually becomes the average bid in this area, an insufficient amount of money would be collected to actually finance the change. Would you be willing to raise your bid? ____no ____yes

(IF YES) To what? ________________________.

QUESTIONNAIRE - BIDDING GAME

PART III

As an alternative to controlling emissions, the power companies could simply compensate or pay people for any damages inflicted upon them associated with reduced visibility. This compensation could be accomplished by having the power companies:

(FOR RESIDENTS) reduce utility rates for the people in the area affected.

(FOR NONRESIDENTS) subsidize reductions in lodging expenses and entrance fees to parks, reservoirs, and lodging in this area.

(DO EITHER 1,2,3,4____ OR 3a,1,2,4____ SEQUENTIALLY. CHECK THE ONE USED.)

1a. Would you be willing to accept a $____ (USE STARTING BID OF $1,5, or 10) reduction per month (in your utility bill) (in park, reservoir and lodging fees) to allow typical visibility as in Column B rather than as in Column A?

b. (REPEAT a. CHANGE COLUMN B TO COLUMN C)

c. (REPEAT a. CHANGING B TO C AND A TO B.)

d. Again the power plants and their emissions may be out in the open, such as in Column D with emissions level C or hidden as in Column A with almost no emissions. (REPEAT a. CHANGE B TO COMBINATION OF C + D.)

ORIGINAL BIDS

1a. $____________
b. $____________
c. $____________
d. $____________

(IF ZERO BID)

2i. Did you bid zero because you believe that (HAND RESPONDENT THE AUXILLIARY SHEET. MORE THAN ONE ANSWER IS ACCEPTABLE BUT NOT ENCOURAGED. RECORD ANSWER HERE:) ____

____.

(IF INFINITE BID)

2ii. You have said you could not be compensated enough to accept the level of emissions depicted in Column ___. Could you be compensated by a lump sum sufficient to relocate to a similar location in New Mexico, Colorado, Arizona, or Utah? ____yes ____no.

If yes, what would be sufficient compensation: ______ (BID DOWN BY 10% INCREMENTS.)

If no, what would you do if situation B (C) were the case? __________

(ATTEMPT TO CONVERT THIS TO A $ FIGURE.)

3a. Suppose you were told that the average payment people were willing to accept, found in other studies of similar circumstances was actually:

$2.25 per month to just compensate them for damages associated with the reduced visibility as depicted in Column B rather than A.

$2.50 per month to just compensate them for damages associated with the reduced visibility as depicted in Column C rather than A.

$ .25 per month to just compensate them for damages associated with the reduced visibility as depicted in Column C rather than B.

$3.75 per month to just compensate them for damages associated with the change in visibility associated with the combination of Columns C + D, rather than A.

3b. i. Given this information, what now would be your bid to allow visibility as in Column B rather than as in Column A?

ii. (SUBSTITUTE C FOR B ABOVE)

iii. (SUBSTITUTE C FOR B AND B FOR A ABOVE)

iv. (SUBSTITUTE D FOR B ABOVE)

REVISED BIDS

3b. i. $__________

ii. $__________

iii. $__________

3c. Why did/didn't you change your bid? ______________________________

4. As another way to estimate compensation, what is the minimum amount of recreational activity of your choice, such as a trip or outing, that you would accept to compensate you for any damages inflicted upon you due to the reduced visibility of Column B? ______________________________

Column C? ______________________________

Column D? ______________________________

(IF THE RESPONDENT HAS TROUBLE ANSWERING, GIVE HIM AUXILLIARY SHEET WITH CHOICE IN EACH CASE ASK WHAT IS THE VALUE TO THIS?)

VALUE OF RECREATION

i. $__________

ii. $__________

iii. $__________

QUESTIONNAIRE - BIDDING GAME

PART IV.

QUESTIONS 1, 2, AND 3 REQUIRE THE RESPONDENT TO HAVE THE AUXILIARY SHEET

1. If you don't mind and for the purpose of this study only, could you please give me the letter corresponding to the category into which your annual income would fall? ____________________

2. Could you please give me the letter corresponding to your educational background? ______________

3. Could you please give me the letter corresponding to your ethnic background? ________________

4. Have you contributed either time or money to any environmental cause or organization recently? ____yes ____no. IF YES, about how much? ______.

For the following questions, would you respond as best as possible with either:

not at all, to some degree, or greatly.

5. In your opinion, how much do you believe the development of the local power plants has positively affected the business of your employer?
   ____not at all ____to some degree ____greatly

6. How has the power plant development positively affected your career?
   ____not at all ____to some degree ____greatly

7. Do you think a typical daily visibility similar to Column C, if caused by emissions, would:
   a) shorten your life? ____not at all, ____to some degree, ____greatly
   b) require you to spend more money on drug items or doctors' fees?
      ____not at all, ____to some degree, ____greatly
   c) make it harder to do your work? ____not at all, ____to some degree,
      ____greatly
   d) make your life less pleasant? ____not at all, ____to some degree,
      ____greatly

8. On a scale of 1 to 5, where 1 represents conservative, 3 moderate, and 5 liberal, where would you place yourself politically on a national level?
   ______________ ______.

9. On a scale of 1 to 5, where 1 represents conservationist and 5 developer, where would you place yourself environmentally on a national level? ____

QUESTIONNAIRE - BIDDING GAME

PART V.

COMPLETE THIS SECTION IMMEDIATELY AFTER THE INTERVIEW BUT APART FROM THE INTERVIEWEE'S PRESENCE. YOU, THE INTERVIEWER, ARE TO ANSWER THE QUESTIONS.

neatness of house interior: sloppy, fairly neat, did not see.

neatness of house exterior: sloppy, fairly neat, did not see.

appr ximate cost of home: $______. ADDRESS OF HOUSE:____________________

Write a couple of sentences on your impression of the interviewee's veracity and the extent to which he had his wits about him.

Does the interviewee seem to have vision problems?

If yes, why?

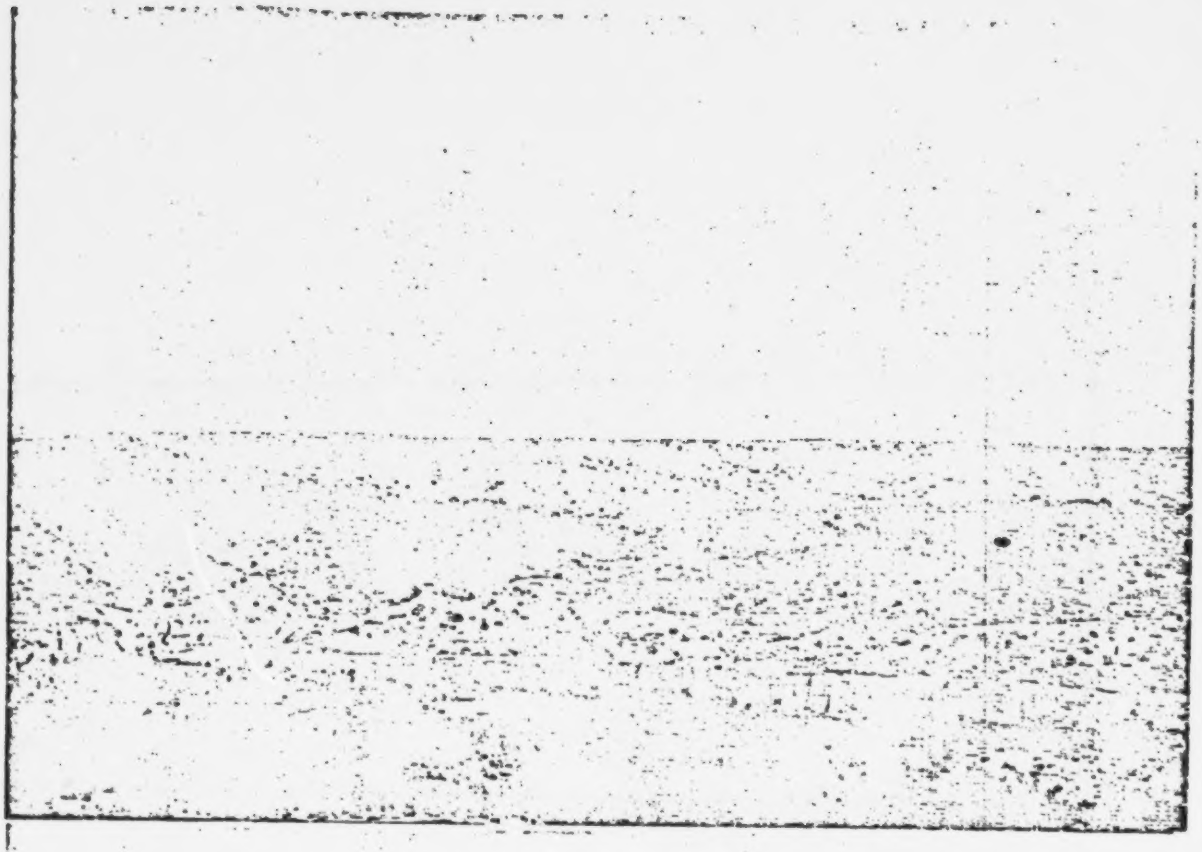
Did the interviewee lose patience? At what point did this loss of patience first become noticeable?

NAME OF INTERVIEWER________________________________

Date of interview______________________

Location of interview____________________

Time of interview______________________



C. South Coast Air Basin Study

This section presents the basic survey instrument employed in the South Coast Air Basin Study. As discussed, the initiation point for the survey instrument was either acute health effects or aesthetic effects. Three basic areas existed (good, fair, bad). Thus the following combinations existed for survey instrument types.

1. Format for A area moving to B (Aesthetic)
2. Format for A area moving to B (Acute)
3. Format for A area moving to C (Aesthetic)
4. Format for A area moving to C (Acute)
5. Format for B area moving to C (Aesthetic)
6. Format for B area moving to C (Acute)
7. Format for C area to C* (Aesthetic)
8. Format for C area to C* (Acute)

The structure of the different combination was identical. Combination 1 is presented for illustrative purposes.

Table A.1

INDOOR ACTIVITY AND COST LIST

Activity	✓	Hours Per Week				Times Per Week				Location (Map Grid)				Miles Traveled				Direct Costs				% Day	Equipment Replacement Costs	Importance
		A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D			
Indoor Spectator Events																								
Indoor Tennis																								
Raquetball, Handball																								
Table Tennis																								
Bowling																								
Indoor Gardening or Fixing up House																								
General Exercise																								
Organized Sports Events																								
Reading																								
Television																								
Movies																								
Club Activities, Organizations																								
Individual Sports																								
Swimming																								
Visiting Neighbors or Friends																								
Other (specify)																								

Table A.2

OUTDOOR ACTIVITY AND COST LIST

Activity	✓	Hours Per Week				Times Per Week				Location (Map Grid)				Miles Traveled				Direct Costs				% Day	Equipment Replacement Costs	Importance
		A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D			
Outdoor Spectator Sports																								
Tennis																								
Biking																								
Beach Activities																								
General Exercise																								
Fishing																								
Swimming																								
Sailing																								
Jogging/Walking																								
Hobbies, Arts & Crafts																								
Outdoor Gardening or Fixing up House																								
Golf																								
Hiking																								
Camping																								
Organized Sports Events																								
Individual Sports Events																								
Other (specify)																								

GAME FOR A AREA MOVING TO B, AESTHETIC

Questionnaire #_____
Interviewer #_____

INTRODUCTION

1. In a typical week how much day and night leisure time do you have available? This includes both weekdays and weekends. By leisure, I mean the time you do not spend eating, sleeping, or working to earn a living. ____ hours

2. Has air pollution influenced where you have chosen to live? Yes[ ] No[ ]

3. Has air pollution influenced where you have chosen to work? Yes[ ] No[ ]

4. Would you classify the air quality in the area where you live as:
Good[ ] Fair[ ] Poor[ ]

5. Would you classify the air quality in the area where you work as:
Good[ ] Fair[ ] Poor[ ]

5a. What is your occupation?________________________________

6. Are you aware of any health hazards due to air pollution? Yes[ ] No[ ]

7. How long have you lived in the Los Angeles area? ____________________

8. How much longer do you plan to live in the los Angeles area?____________

9. Do you think automobile emission standards should be: Increased[ ] Decreased[ ] Kept the Same[ ]

ADMINISTER INDOOR AND OUTDOOR ACTIVITY AND COST LISTS (TYPICAL WEEK) CHECK THE TOTAL TIME CONSTRAINT

Bidding Game for Residents of Area A

Here are three photographs representing average levels of visibility for the three different regions of the Los Angeles Area shown on this map. Picture A represents poor visibility; Picture B represents fair visibility; and Picture C represents good visibility.

Public officials are strongly considering the possibility of trying to reduce the levels of emissions throughout the Los Angeles Area. Such action could require additional funds which might be generated by (a monthly charge, an extra charge in your utility bill) for as long as you live in the Los Angeles area. These funds will be used to help finance air quality improvements in the Los Angeles area.

Aesthetic

The Los Angeles area has some very beautiful background scenery. Because of automobile and industrial emissions, there is a haze which reduces and distorts the ability to see this scenery. This means that many people have to leave Los Angeles and travel long distances to be able to enjoy views which could be visible from their homes if these emissions were reduced.

As indicated by the map, you live in an area which has been classified as having poor air quality relative to the rest of the Los Angeles area. Picture A represents the visibility level which typically occurs in your area. I am only interested in how you value being able to see long distances.

If the level of emissions could be reduced in the Los Angeles area so that visibility conditions would be represented by Picture B instead of A, not only in the B area but also in your area, and if the air would be cleaned up to this level in (2, 10) years, would you pay (a monthly charge, an extra charge in your utility bill) of ($1, $10, $50) for as long as you live in the Los Angeles area?

[ ] DO FOLLOWING ONLY IF CHECKED

LIFE TABLE: Here is a table that might help you. It shows the total amount you would pay for as long as you live in Los Angeles for various amounts of monthly payments.

RECORD MAXIMUM BID__________

Would you consider moving to a new location in the los Angeles area if air quality were like Picture C everywhere? Yes[ ] No[ ]

IF YES:

Where would you move? (GRID LOCATION ON MAP)________________

Bidding - Aesthetics and Acute Health

The questions I asked earlier were only concerned with your perception of visibility. This section deals with not only visibility but with short term health effects which may be aggravated by air pollution. Some pollutants in high concentrations cause eye irritation for many individuals. Studies have shown that about half of the population experiences eye irritation under conditions represented by Picture A; about one-fourth experiences eye irritation under conditions represented by Picture B; while no one experiences these irritating effects when conditions are represented by Picture C.

Since you reside in area A, which has been classified as having poor air quality, there is reduced visibility as well as irritating health effects as compared with B. If the level of emissions could be reduced in the Los Angeles area so that visibility and irritating health effects were represented by Picture B not only in the B area but also in your area, and if the air would be cleaned up to this level in (2, 10) years, would you pay a (a monthly charge, an extra charge in your utility bill) of (START BIDDING WITH PREVIOUS MAXIMUM BID) for as long as you live in the Los Angeles area?

[ ] DO FOLLOWING ONLY IF CHECKED

Life Table: Here is a table that might help you. It shows the total amount you would pay for as long as you live in Los Angeles for various amounts of monthly payments.

RECORD MAXIMUM BID______

REVISIONS IF NECESSARY_______

Would you consider moving to a new location in the Los Angeles area if air quality were like Picture C everywhere? Yes[ ] No[ ]

IF YES:

Where would you move? (GRID LOCATION ON MAP)________

Substitutions

Aesthetic; Original Position A; Movement to B

NON-ZERO BIDS:

You stated that you would pay $_____ per month for as long as you live in the Los Angeles area if visibility improved from A to a condition like that shown in B, if this could be accomplished in (2, 10) years. If you actually paid this amount in order to help finance air pollution control programs, you would have less money to spend overall. However, because you said you would pay some amount of money, you are indicating that clearer air is something you value. Consequently, when conditions like B are achieved, even though you have paid money to help improve the visibility, this does not mean that your standard of living is worse than before because now you will be living and recreating in a less polluted area.

If the visibility conditions were to improve from A to B in your area, would the improved conditions change the pattern of your leisure activities? This could be changes in time per week, location, or frequency. Yes[ ] No[ ]

IF NO, GO TO NEXT BIDDING GAME
IF YES, THEN:

A. Administer indoor and outdoor activity and cost list
B. Check time constraint____

ZERO BIDS:

Although you told me that you would not pay anything to have visibility improve throughout the Los Angeles area to like that shown in Picture B, would the improved conditions change the pattern of your leisure activities? This could be changes in time per week, location, or frequency. Yes[ ] No[ ]

IF NO, GO TO NEXT BIDDING GAME
IF YES, THEN:

A. Administer indoor and outdoor activity and cost lists
B. Check time constraint______

Substitutions

Aesthetic + Acute; Original Position A; Movement to B

NON-ZERO BIDS:

With the extra information on possible short term health effects when conditions are like A, you said that you would pay $_____ per month for as long as you lived in the Los Angeles area if conditions improved from those associated with Picture A to conditions shown in Picture B, and if this could be accomplished in (2, 10) years. As before, because you said you would pay some amount of money, you are indicating that clearer air is something you value. Consequently, when conditions like A are achieved, even though you have paid monay to help improve the visibility and to lessen short term health effects, this does not mean that your standard of living is worse than before because now you will be living and recreating in a less polluted area.

If conditions improved so that Picture B were representative of the entire area, with no visibility problems or irritating effects, would the improved conditions change the pattern of your leisure activities? Yes[ ] No[ ]

IF NO, GO TO NEXT BIDDING GAME
IF YES, THEN:

A. Administer indoor and outdoor activity and cost lists
B. Check time constraint_____

ZERO BIDS:

Although you told me you would not pay anything to have visibility conditions and short term health effects improve throughout the area to like those shown in Picture B, would the improved conditions change the pattern of your leisure activities? Yes[ ] No[ ]

IF NO, GO TO NEXT BIDDING GAME
IF YES, THEN:

A. Administer indoor and outdoor activity and cost lists
B. Check time constraint_____

Substitutions

Aesthetic + Acute + Chronic; Original Position A; Movement to E

NON-ZERO BIDS:

Given the information that continued exposure to levels of air pollution like those shown in Picture A could actually reduce your life expectancy, you said you would pay $_____ per month for as long as you lived in the Los Angeles area if conditions improved from those in A to those shown in B, and if this could be accomplished in (2, 10) years. Once again, I would like you to think of this expenditure as leaving you as well off as before you paid the money, since you are now living and recreating in a less polluted area.

If conditions improved so that Picture B were representative of the entire area, with no visibility problems or short and long term health effects, would the improved conditions change the pattern of your leisure activities Yes[ ] No[ ]

IF NO, PROCEED TO GENERAL INFORMATION SECTION
IF YES, THEN:

A. Administer indoor and outdoor activity and cost lists
B. Check time constraint_____

ZERO BIDS:

Although you told me that you would not pay anything to have visibility or short and long term health effects improve throughout the Los Angeles area to like those shown in Picture B, would the improved conditions change the pattern of your leisure activities? Yes[ ] No[ ]

IF NO, GO TO GENERAL INFORMATION SECTION
IF YES, THEN:

A. Administer indoor and outdoor activity and cost lists
B. Check time constraint_____

Bidding - Aesthetic, Acute Health and Chronic Health Effects

The quality of the air may also affect your long term health. There is evidence that high concentrations of emissions as represented in Pictures A and B have lasting effects upon the respiratory and circulatory systems in addition to eye irritation and reduced visibility. Evidence shows that, on the average, people who live in areas with concentrations like those in Picture A can expect a reduced lifespan of up to 2 years compared with people who live in conditions represented by B, and up to 3 years when compared with people who live in conditions represented by Picture C.

If the level of emissions could be reduced in the Los Angeles area so that visibility, short and long term health conditions would be represented by Picture B instead of A, not only in the B area but also in your area, and if the air would be cleaned up to this level in (2, 10) years, would you pay (a monthly charge, an extra charge in your utility bill) of (START BIDDING WITH PREVIOUS BID) for as long as you live in the Los Angeles area?

☐ DO FOLLOWING ONLY IF CHECKED

Life Table: Here is a table that might help you. It shows the total amount you would pay for as long as you live in Los Angeles for various amounts of monthly payments.

RECORD BID________

REVISION IF NECESSARY__________

Is there some other payment scheme besides (a monthly charge, an extra charge in your utility bill) that you would prefer? Yes ☐ No ☐

IF YES:

What would it be?____

Would you consider moving to a new location in the Los Angeles area if air quality were like Picture C everywhere? Yes ☐ No ☐

IF YES:

Where would you move? (GRID LOCATION ON MAP)________

GENERAL INFORMATION SHEET: WOULD YOU PLEASE FILL OUT THE FOLLOWING?

1. Age_____

2. Sex: Male[ ] Female[ ]

3. Marital status: Single[ ] Married[ ]

4. Number of persons in your household?_____

5. Your education:_____years. Highest degree obtained:
High School[ ] College[ ] Vocational[ ] Advanced[ ]

6. Address of employment:______________________________

7. Location of employer(s) (GRID LOCATION ON MAP)__________

8. Are there any environmental hazards associated with your job, such as noise, health, or sight? Yes[ ] No[ ] IF YES: What are these hazards?
____

9. What is the percentage of your work time indoors?_______%

10. In a typical work week how much time do you spend on the job?_____hours

11. If you received our pamphlet last week, did you read:

[ ] 0-5 pages
[ ] 5-10 pages
[ ] more than 10 pages

If you live in area A or B:

How much would you pay for this same house (apartment) today if it were located in an area where the air pollution levels were like those shown in Picture C? $__________

If you live in area C:

Do you believe that any part of the value of your home is because you live in a relatively unpolluted part of Los Angeles? Yes[ ] No[ ]
IF YES: How much (% or dollars) ______________

If you live in area B or C:

Would you consider moving if the air pollution problem were as bad as A throughout the entire area? Yes[ ] No[ ]
IF YES: Where would you most likely move? (GRID LOCATION ON MAP)
____

How much do you think it would cost to clean up air pollution in the Los Angeles area to a condition like that shown in Picture C?
$____________

If all citizens were billed equally, how much do you think it would cost each person in order to achieve conditions like that shown in Picture C?
$____________

1. Characteristics of home:

Living Area: ________ square feet

Number of Rooms: _____

Number of Bedrooms _____

Number of Bathrooms: _____

Other Rooms: (PLEASE CHECK)

☐ Den
☐ Family room
☐ Dining room
☐ Enclosed porch
☐ Attic
☐ Basement
_____% Basement finished
☐ Utility room
☐ Other

Scenic View: Yes ☐ No ☐ IF YES: Specify _______________

Number of Stories: (INCLUDE BASEMENT) ______

Remodeled: Yes ☐ No ☐ Don't know ☐

IF YES: Specify previous style and date ______________________________

2. Equipment: (PLEASE CHECK)

☐ Dishwasher
☐ Disposal
☐ Central Air Conditioning
☐ Trash Compactor
☐ Central Heating

Pool: Yes ☐ No ☐

IF YES: Circle whether heated, enclosed, or other (specify) ________

Fireplace: Yes ☐ No ☐

Age of home: _____ years (when constructed)

IF YOU LIVE IN AN APARTMENT, GO TO QUESTION 4

3. a) Year of purchase: ______

   b) Could you please indicate what the purchase price was: $__________

   c) What are your monthly payments: $__________

   d) What do you feel your home is worth in today's market? $__________

   e) What are your property tax payments per year? $__________

   f) How long have you been living in this house? ______ years

GO TO QUESTION 5

4. a) How long have you been living in this apartment: _____ years

   b) Would you indicate your monthly rent? $________

5. What are your insurance payments per year? $________

6. What do you pay monthly for general upkeep around your home (apartment)?

   ____

7. Why have you chosen to live in this area? RANK IN ORDER OF IMPORTANCE, WHERE ONE IS MOST IMPORTANT. CHOOSE TOP FIVE.

   ☐ Attractiveness of area in general
   ☐ Close to work
   ☐ Close to recreation activities
   ☐ Close to friends
   ☐ Close to schools
   ☐ Close to services
   ☐ Close to transportation routes
   ☐ Air quality
   ☐ Affordability of home
   ☐ Low crime rate
   ☐ Prestige of area
   ☐ Quiet neighborhood
   ☐ Other

8. What are your average expenditures per month for food: $___________

9. What are your average expenditures per year for clothing? $___________

10. Please mark the box corresponding to your annual household income.

    ☐ 0-$5,000
    ☐ $5,000- $10,000
    ☐ $10,000-$15,000
    ☐ $15,000-$20,000
    ☐ $20,000-$25,000
    ☐ $25,000-$30,000
    ☐ $30,000-$35,000
    ☐ $35,000-$40,000
    ☐ $40,000-$50,000
    ☐ $50,000-$60,000
    ☐ $60,000-$80,000
    ☐ Over $80,000

1. Do you own or share in the ownership of a motor vehicle? Yes[ ] No[ ]

Type of Vehicle(s)

__________Model ______Year

__________Model ______ Year

__________Model ______ Year

2. How many licensed drivers are in your family? _______

3. How many miles per gallon do you get for each car in the city?

________mpg

________mpg

________mpg

How many miles do you and your family typically travel in your automobile per week? ______miles

4. How many hours do you and your family spend in a typical week commuting to:

Work or school ______ hours

Shopping ______ hours

Recreational activities ______ hours

5. Do you participate in a car pool? Yes [ ] No [ ]

6. How much do you spend each month on:

a) Gasoline costs $______

b) Maintenance costs $______

c) Public transportation fares $______

d) Insurance payments $______

7. Did you take a vacation within the last year where you were away from home for more than 4 days? Yes[ ] No[ ]

IF YES: About how much were your expenditures on this trip? $_________

1. Have you ever had any of the following? (PLEASE CIRCLE)

   a) High blood pressure
   b) Heart trouble
   c) Stroke
   d) Chronic bronchitis
   e) Asthma
   f) Chronic nervous trouble
   g) Cancer
   h) Tuberculosis

2. Have you ever had trouble with the following? (PLEASE CIRCLE)

   i) Pain in the heart or tightness or heaviness in the chest
   j) Trouble breathing or shortness of breath
   k) Frequent headaches
   l) Constant coughing or frequent heave chest colds
   m) Frequent eye irritations
   n) Allergies
   o) Nose and throat irritation

3. Are any of these (the above) conditions aggravated (or made worse) by heavy air pollution? Yes[ ] No[ ]

   IF YES: Which ones? (LIST LETTERS CIRCLED) ____________________

4. Do you suffer from any other diesases which could be made worse by poor air quality? Yes[ ] No[ ] Specify ____________________

5. Do you or any member of your family have any physical disabilities which limit your activities? Yes[ ] No[ ]

6. Would conditions like those in Picture C, if they occurred over the entire area?

   a) Make your life more pleasant — Not at all[ ] To some degree[ ] Greatly[ ]

   b) Require you to spend less money on drug items or doctor's fees — Not at all[ ] To some degree[ ] Greatly[ ]

   c) Make it easier to do your work? — Not at all[ ] To some degree[ ] Greatly[ ]

7. Do you enjoy doing your leisure activities more during the day or during the night? Day Night Makes no difference

8. Do you smoke? Yes[ ] No[ ] IF YES: How many packs per day?__________

9. Do you take medication regularly? Yes[ ] No[ ]
   IF YES: Monthly expense on this medication? $______/month

10. How much do you spend monthly on medical problems associated with air pollution effects? $______/month

11. How much do you spend yearly for doctor's fees? $_________/year

12. How much do you spend yearly on medical and life insurance? $_____________/year

13. Have you purchased any items to reduce your exposure to air pollution (such as carbon filters)? Yes[ ] No[ ]
IF YES: What items?____

1. Which one of these statements applies to you? (CHECK ONE)

   ☐ I have not been bothered by air pollution.
   ☐ I have been somewhat bothered by air pollution.
   ☐ I have been bothered quite a lot by air pollution.

2. Do you believe that air pollution in Los Angeles: (CHECK ONE)

   ☐ Has become worse since you have lived here.
   ☐ Has stayed about the same since you have lived here.
   ☐ Has gotten better since you have lived here.

3. What do you think should be done about air pollution? (CHECK ONE)

   ☐ Ignored
   ☐ Reduced

4. Please rank the following problems in terms of importance (most to least) as the major issues facing the community. (CHOOSE TOP FIVE)

   ☐ Juvenile delinquency
   ☐ Communicable disease
   ☐ Unemployment
   ☐ Air pollution
   ☐ Car accidents
   ☐ Crime
   ☐ Nuclear energy
   ☐ Alcoholism
   ☐ Water pollution
   ☐ Energy
   ☐ Congestion
   ☐ Other

5. Do you believe that air pollution in the Los Angeles area:

   ☐ Cannot be reduced below its present level
   ☐ Can be reduced below its present level
   ☐ Can be almost completely eliminated

6. What do you think the words "air pollution" mean to most people in the Los Angeles area? Do they mean:

   a) Frequent bad smells in the air Yes ☐ No ☐
   b) Too much dirt and dust in the air Yes ☐ No ☐
   c) Frequent haze or fog in the air Yes ☐ No ☐
   d) Frequent irritation of the eyes Yes ☐ No ☐
   e) Frequent nose or throat irritation Yes ☐ No ☐
   f) Other Yes ☐

7. Have you read or seen anything in the newspaper recently about air pollution? Yes ☐ No ☐

8. When you read the newspaper, do you generally choose to read articles on air pollution? Yes ☐ No ☐

9. Do you consult the daily air pollution index before engaging in any activities? Yes[ ] No[ ]

IF YES: What kind of activities? ______________________________
____
____

1. If you received our health pamphlet, what do you think about it?

   - ☐ Did not read
   - ☐ Very informative
   - ☐ Hard to understand
   - ☐ Scientific mumbo-jumbo
   - ☐ Made me more concerned about health effects
   - ☐ Had no influence on me

2. Here is a list of words and phrases. Select two which describe how you feel about your participation in this survey.

   - ☐ Stimulating
   - ☐ Just tolerable
   - ☐ A waste of time
   - ☐ Educational
   - ☐ Boring
   - ☐ An invasion of privacy
   - ☐ Interesting
   - ☐ Kind of fun
   - ☐ Hard to take seriously

3. Here is a different list of words and phrases. Select two which describe how you feel about the questionnaire.

   - ☐ Relevant
   - ☐ Credible
   - ☐ Likely to influence air quality control
   - ☐ Unrealistic
   - ☐ Pretty flakey
   - ☐ Unlikely to have any effect on air quality control
   - ☐ Irrelevant

4. Finally, here is another list of words and phrases. Select one from each column to describe how you feel about your answers to the questionnaire.

   Column 1

   - ☐ Quite accurate
   - ☐ There was no way I could come up with accurate answers.
   - ☐ Accurate in a "ball park" kind of way.

   Column 2

   - ☐ A fairly good guide for valuing air quality
   - ☐ A good guide for valuing air quality.
   - ☐ A poor guide for valuing air quality.

THANK YOU FOR YOUR COOPERATION.

Figure 4.4a
(Good)
Photograph Depicting Observation Paths for "Good" Visibility

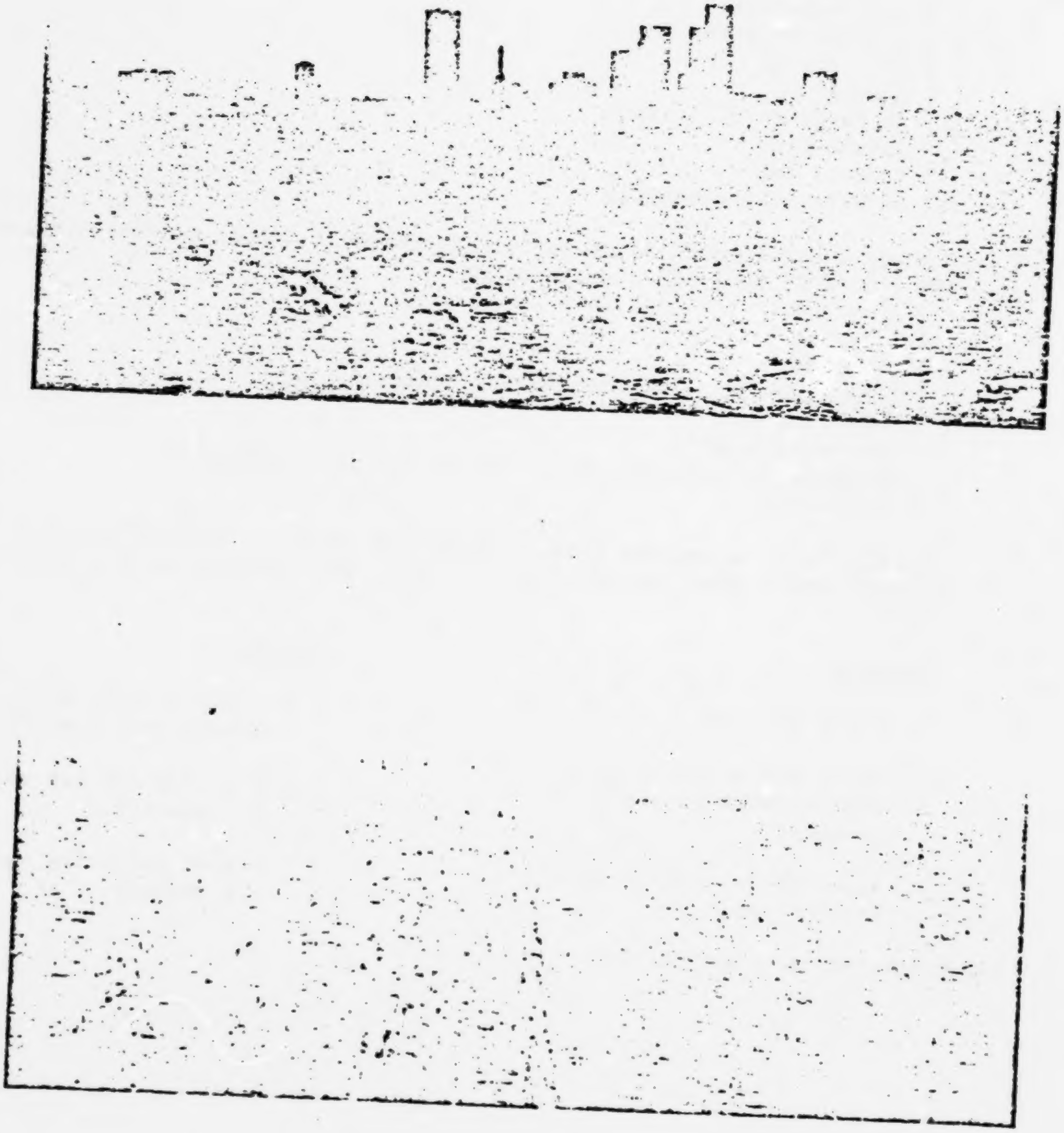


Figure 4.4b
(Fair)
Photograph Depicting Observation Paths for "Fair" Visibility

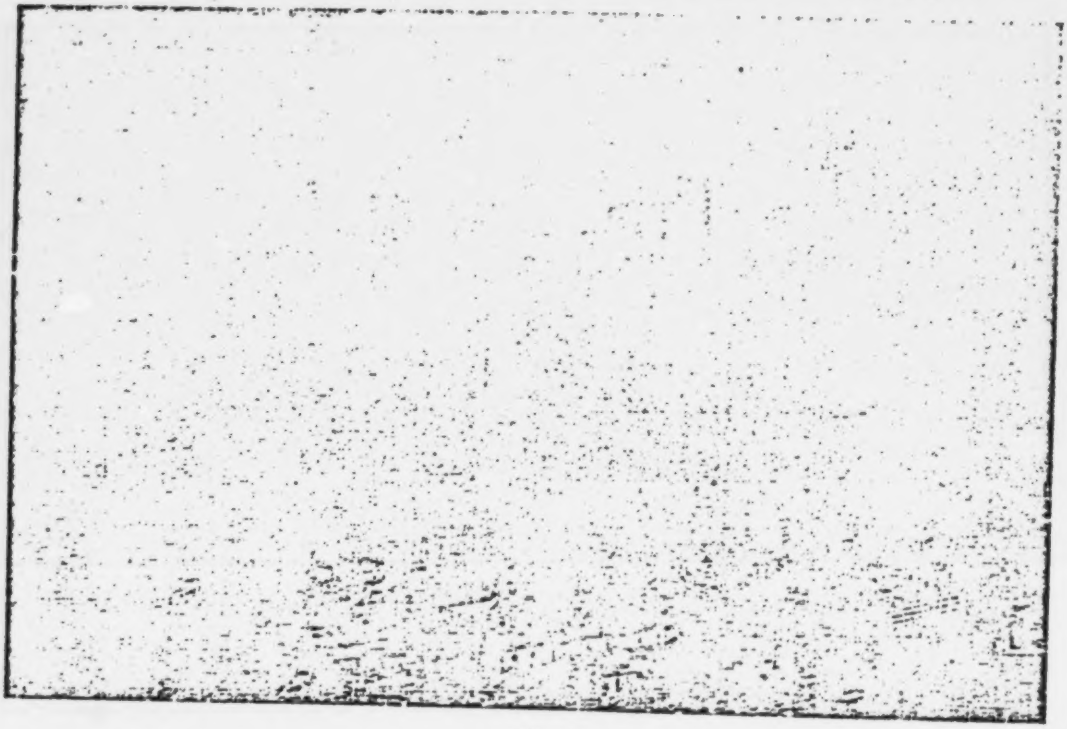
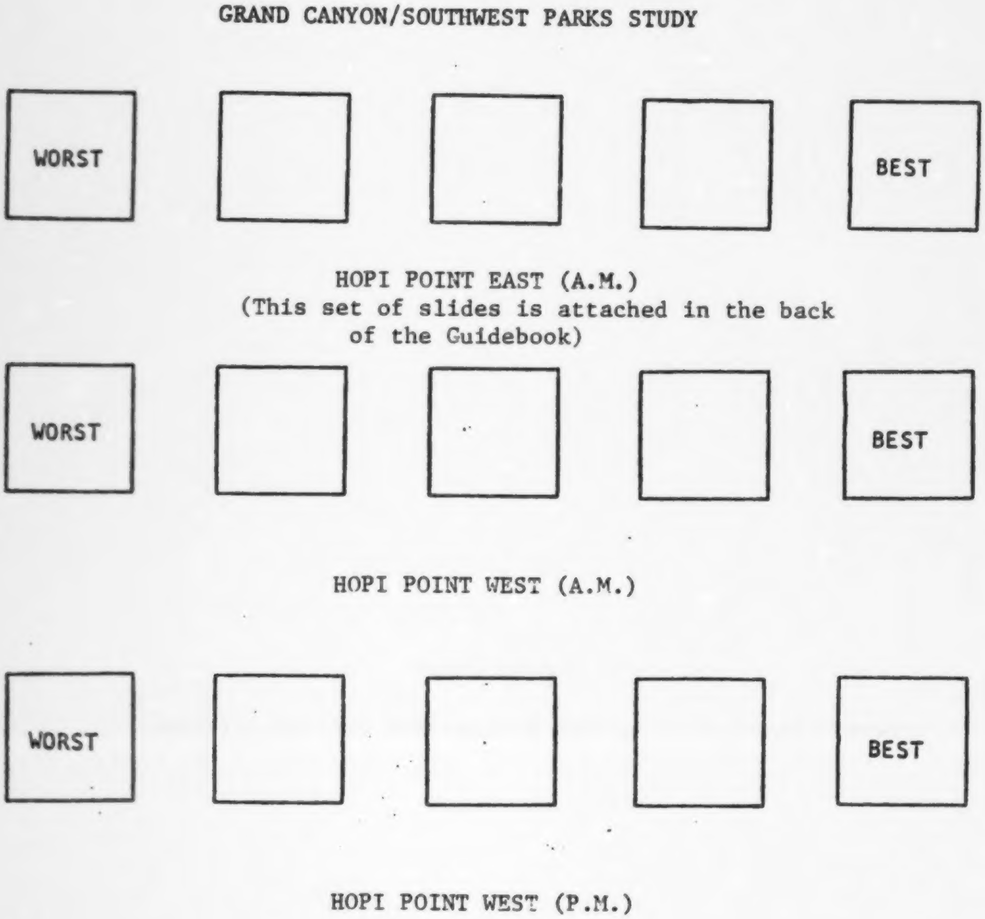


Figure 4.4c
(Poor)
Photographs Depicting Observation Paths for "Poor" Visibility

D. GRAND CANYON STUDY

(Questionnaire and Complete Picture Set Not Yet Released)


GRAND CANYON/SOUTHWEST PARKS STUDY
WORST
BEST
HOPI POINT EAST (A.M.)
(This set of slides is attached in the back of the Guidebook)
WORST
BEST
HOPI POINT WEST (A.M.)
WORST
BEST
HOPI POINT WEST (P.M.)

Grand Canyon Photograph Board

Figure 1

HOPI POINT EAST (A.M.)
(from Grand Canyon)

SHIPROCK 9AM

TRUMBULL MT. 9AM
(from Zion)

Regional Photograph Board

Figure 2

GRAND CANYON PLUME BOARD

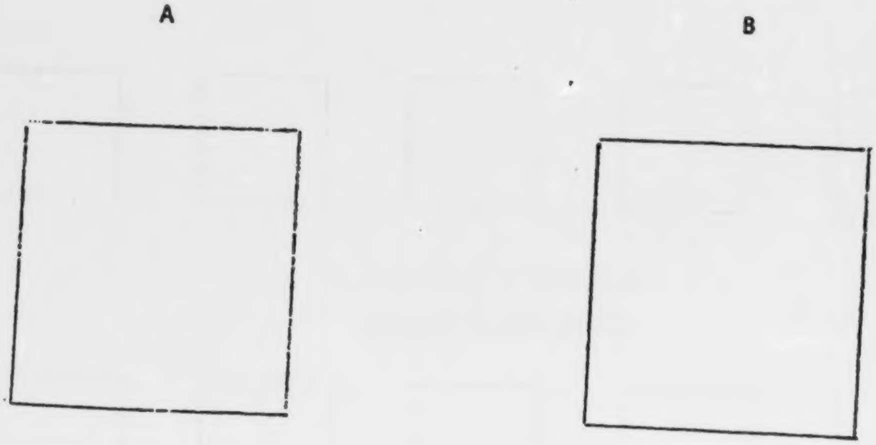


Figure 3

E. WATER RESOURCE COUNCIL SUGGESTED CONTINGENT MARKET VALUATION TECHNIQUES TO ESTIMATE RECREATION BENEFITS

This section reproduces the Water Resource Council's guidelines on contingent market estimation techniques as contained in the Federal Register (1979).

(3) *Contingent Valuation (Survey) Methods.* (i) *Overview.* (A) Contingent valuation methods (CVM's) obtain estimates of changes in NED benefits as a result of changes in the quantity of recreation consumed by directly asking individual recreationists. V_{jk} is an individual household's willingness to pay (WTP) for changes in quantity, Q, of recreation at site j. Individual values may be aggregated across the population of the market area for facility j by summing V_{jk} for all n households in the market area:

$$V_j = \overset{n}{\underset{k=1}{}} V_{jk}$$

(B) Contingent valuation methods consist of designing and using simulated markets to identify the value of recreational amenities just as actual markets would, if they existed. Three basic steps are involved: (1) the analyst establishes a market to the respondent; (2) he permits the respondent to "use" the market to make "trades" and establish prices or values which reflect the respondent's individual valuation of the recreation opportunities "bought" or "sold"; and (3) the analyst treats the values reported by the respondent as individual values for the recreation, contingent upon the existence of the market. The respondent's bids are used with the data contained in the market description (step 1) to estimate the aggregate value of the recreation being studied.

(C) Contingent valuation methods are particularly appropriate (1) for evaluating projects likely to be one of several destinations visited on a single trip, and (2) where a project results in a relatively small change in quality of recreation at a site. Contingent value results may be adversely affected unless questions are carefully designed and pretested to avoid several possible kinds of response bias. Several techniques are available for obtaining the individual bids, which are the basic data for CVM.

(ii) *Iterative Bidding Formats.* (A) Iterative surveys are distinguished from other contingent valuation methods in that, following establishment of the market and a complete description of the recreational good, service, or amenity to be valued, the respondent reacts to a series of values posed by the enumerator. The respondent answers "yes" or "no" to questions asking if he is willing to pay the stated amount of money to obtain the stated increment in the recreational good. The enumerator iteratively varies the value posed, until the highest amount which the respondent is willing to pay is identified. This amount is treated as the respondent's bid for the specified increment in the recreational good.

(B) Iterative bidding techniques are most effectively applied in personal interview surveys. Mail survey formats have also been used in research studies. These typically ask the respondent to react ("yes" or "no") to a small number of different but specified values stated in iterative questions and, finally, asked an open-ended question: "Now, write down the maximum amount you will be willing to pay. $———." At the present time, mail survey applications of the iterative bidding technique have not been adequately tested and cannot be rcommended.

(C) The recreation facilities to be evaluated will be described in quantity, quality, time, and location dimensions. These should be hypothetical in the sense that they do not precisely describe features of actual sites or proposed projects, but should be described with sufficient precision that the respondent has adequate information on which to base a valuation. To permit estimation of regional models, quantity, quality, and location dimensions should be varied and the iterative bidding exercise repeated. Verbal descriptions should be precise, and in addition, wherever practicable, the pertinent aspects of the facilities should be displayed or depicted using nonverbal stimuli (e.g., photographs, artist's drawings, motion pictures, scale models, etc.).

(D) The good to be valued is "the right to use * * * (the recreation facility). * * * for one year." When the good is defined in this way, the V_{jk} obtained are *annual* measures of the individual's willingness to pay for the existence of a given increment or decrement in recreation opportunities which would be provided at site j. Where there are compelling practical reasons to use a bidding format which defines the good in some other terms (e.g., day of use, trip, etc.), sampling and aggregation procedures must be designed so that the annual values are calculated.

(E) The institutional rules pertaining to the hypothetical market will be described in sufficient detail that the respondent knows his rights and the rights of all others in the market. These rules should be realistic and credible. They should place the respondent in a role, and encourage market behavior with which he is familiar. They should be of a kind generally viewed as just, fair, and ethically sound. They should be nonthreatening: in particular, formats which threaten the respondent with a welfare shock that he may view as unfair should be avoided.

(F) Vehicles should be carefully pretested. At the pretest stage, always include a neutral vehicle, e.g. "the money collected will be placed in a trust fund and devoted entirely to providing * * * [the good]."

(G) The respondent should be provided price or value information and asked "would you buy?," with the clear understanding that "if no, then you would go without." The question "would you be willing to pay . . ?" should be avoided since this may be interpreted by some respondents as an appeal for voluntary contributions. Instead the question must be worded so as to suggest the pragmatic, if harsh, "take it, or leave it" atmosphere of the marketplace.

(H) Depending on the answer, "yes" or "no," the price or value is varied iteratively and the question is repeated until the respondent's point of indifference between the money and the good is identified. Early iterations may change the price widely until the enumerator senses that he is approaching the respondent's indifference point. Then, iterative price variations will become finer.

(I) The starting price quote (called "starting point") will vary across respondents. The particular starting point assigned to a given respondent will be chosen randomly.

(J) The method of payment (called the payment vehicle) should be specified. Payment vehicles which may, in and of themselves, generate an emotional reaction should be avoided; emotional reactions to a specific payment vehicle introduce a confusing element into the bid data. Vehicles based on tax increments, utility bill increments, and hunting or fishing license fee increments may introduce such problems.

(K) General formats for iterative bidding questions are presented below. (Specific examples follow.) The question form must be specific to the particular measure of value to be elicited from the respondent. WTP formats should always be used. However, WTP formats may be incremental (willingness to pay for an increment in a desired recreational opportunity) or decremental (willingness to pay to avoid a threatened decrement in a desired recreational opportunity). The incremental version has two major advantages: it is the theoretically correct measure and, since it confronts the respondent with the (hypothetical) chance to pay for a desired good, it is not likely to provoke an offended reaction on the part of the respondent. The decremental version, which asks the respondent to pay to avoid a change he does not want, may seem unfair or morally offensive to at least some, and thus may elicit biased or otherwise unreliable value estimates. The incremental version is preferred, wherever it is credible.

(L) The incremental version may not be credible where the real world experience is typically one of decrements rather than increments. To determine the value of remaining "unspoiled natural environments" in a world where these are fast disappearing, questions asking "if a new unspoiled natural recreation environment could be created and the right to use it would cost, * * *, would you buy?" may be rejected as fantasy by some respondents. In these circumstances, it may be necessary to resort to decremental formats. Since reasonable doubts can be raised, *a priori*, about the efficiency of WTP formats in this circumstance, the following precautions are essential: take great care to design the best (i.e., most consistent and plausible, and least offensive) formats; and pretest at least two differenct formats, in order to permit statistical testing for differences in the performance of alternative formats.

(M) General examples of the WTP formats are:

WTP incremental: "If you had the opportunity to obtain * * * [describe an increment in recreation facilities]. * * * [describe hypothetical market rules and payment vehicle] * * * would you pay * * * [starting price] * * *? Yes (pay)———. Or would you refuse to pay, and make do without * * * [the increment]? No(pay)———." Reiterate with new prices until the highest price eliciting a "yes" response is identified.

WTP decremental (example 1): "* * * [describe a decrement in recreation facilities] * * * will occur unless * * * [describe market rules and payment vehicle]. Would you pay * * * [starting price] * * * to avoid * * * [the decrement]? Yes(pay)———. Or would you refuse to pay, and thus permit * * * [the decrement]?———."

WTP decremental (example 2): " * * * [describe a recreation facility which is currently available to respondent] * * * is currently available * * * [describe existing market rules, existing payment vehicle, and existing price]. Unless * * * [the existing price] * * * is increased. * * * [describe a decrement in recreation facilities] * * * will occur. Would you pay * * * [starting price, which is some increment over the existing price] * * *, in order to prevent * * * [the decrement]? Yes(pay)———. Or would you refuse to pay, and thus permit [the decrement]? No(pay)———." Reiterate * * *

(N) Since some respondents may bid only zero amounts to WTP questions, it is important to identify which zero bids represent true zero valuations and which, if any, represent a protest against the rules or payment vehicles used in the iterative bidding format. Check questions should always be used to probe "zero" responses to WTP formats, e.g., "Did you bid zero because: (Check one).

(1) You believe * * * [the stated increment] * * * would be worth nothing to you?

(2) You believe * * * [the vehicle] * * * is already too high?

(3) You believe * * * [the statement increment] * * * would be of value, but you do not think it is fair to expect * * * [the respondent's class of citizen e.g. hunting license holders, utility customers] * * * to pay for it."

(O) Given this kind of question, answers (2) and (3) are "protest" responses, addressed not to the value of the good but to some element of the question format. Protest bids should be recorded but eliminated from calculations to estimate values. In pretests, formats that elicit more than 15 percent protest responses should be discarded, since a high incidence of protest bids may be an indication that some nonzero bids are also distorted.

(iii) *Noniterative Bidding Formats.* (A) Noniterative bidding formats are adaptable to implementation with mail surveys. There are two kinds of noniterative formats: *(1)* close-ended formats, which ask respondents to react ("yes" or "no") to a single stated value, and *(2)* open-ended formats, which ask the respondent to write down the maximum amount he would be willing to pay. A variant of the second kind of format asks the respondent to either select his maximum WTP from a list of stated discrete values or write down his maximum WTP. Noniterative bidding formats are not likely to be as reliable as iterative formats.

(B) The use of noniterative mail survey formats is generally discouraged. It is permissible only for recreation benefit analysis of small projects. Mail survey formats will, insofar as is practicable, retain the basic attributes of the personal interview formats described above. Survey instruments should be printed using a process that permits reproduction of color photographs and, if appropriate, other nonverbal stimuli.

(C) The sample should be divided, using open-ended bidding formats with one half and close-ended formats with the other half. The bids obtain using these two kinds of formats should be analyzed to determine if the format influences the results obtained, to a significant degree. Examples of these formats are presented below.

(D) *Open-ended:* Due to pressures of population growth and economic development, 10 miles of trout stream such as that shown in photograph ——— are likely to be converted to other uses (e.g., a reservoir) and thus lost for trout fishing. Assume the only way to preserve this 10-mile stretch for trout fishing is for trout fishermen to agree to buy an annual pass to fish in that stream segment. The money collected would pay for preservation of the stream section. If the stream segment was ——— miles from your home, and you could expect to catch ——— trout in a typical day's fishing there, what is the *maximum amount* you would pay for the annual fishing pass?

——————— Dollars per year ———————

(E) *Closed-ended:* (information presented does not change: the final question reads:) * * * and an annual fishing pass costs $——— (assign dollar amounts randomly to respondents). Would you buy one? Yes ——— No ———

(iv) *Use Estimation with CVM's.* (A) All of the contingent valuation procedures described thus far generate annual value estimates directly, instead of generating, first, values per user day and, then, estimates of expected user days. The "annual value estimation" procedure is superior, in that it is more reliable, it automatically corrects for the economic influence of existing recreation opportunities, and it is better adapted to estimating activity and existence values, where both are important.

(B) However, if for some reason values per user day are desired by analysts, contingent valuation formats can be designed to estimate such values. Questions are worded in terms of a day's activity rather than an annual valuation. Great care must be taken in the case of proposed increments to determine the respondent's valuation of a day at the proposed site, given the continued availability of existing sites. Estimates of use may be made *either* by collecting such information as part of the survey or by other approved methods.

(C) To collect use information in the survey, proceed as follows:

(1) For *decrements* in recreation opportunities, ask: how many trips the household made *(i)* last year and *(ii)* in a typical year, if last year was unusual for any reason; how many days did the trip last; and how many household members participated in each trip.

(2) For *increments,* ask: *(i)* the same information as for decrements, but pertaining to existing recreation sites similar to the proposed increment. Then, if the proposed increment (described with verbal and nonverbal stimuli) were made available: *(ii)* "how many trips, how long, and how many family members" for the proposed increment; and *(iii)* "how many trips, how long, and how many family members" *in total for both the existing and proposed sites.*

(v) *Using Contingent Valuation Methods.* Contingent valuation methods can be used to develop value estimator models or to estimate recreation benefits for a specific proposed project. These two uses are discussed below.

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16. ABSTRACT

The Visibility Benefits Assessment Guidebook provides information on the following:

The conceptual economic framework and definitions of monetary benefit measures for visibility improvements derived from consumer utility theory and demand analysis.

An overview of required inputs from other disciplines to aid the economic analyst in communicating with physical scientists, psychologists, and sociologists in performing a complete benefit analysis.

The applications, theoretical foundations and strengths and weaknesses of economic techniques currently used to measure benefits of visibility and overall air quality changes. These techniques include bidding methods, property value studies, travel cost studies, the ranked attribute approach and others.

A summary of the start to finish research tasks for a complete visibility benefit analysis with suggested step-by-step decision and application guidelines.

Five case studies of actual applications for both of the two predominant techniques--bidding methods and the hedonic property value approach--and a comparison of their procedures and results.

A glossary, annotated bibliography, and an appendix with sample picture sets and questionnaires for the bidding method are also included.

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